



Issued under the authority of the Home Office
(Fire and Emergency Planning Directorate)

Fire Service Manual

Volume 2

Fire Service Operations



Electricity

HM Fire Service Inspectorate
Publications Section

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(Fire and Emergency Planning Directorate)

Fire Service Manual

Volume 2

Fire Service Operations

Electricity

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**The Fire Service
College**



HM Fire Service Inspectorate Publications Section
London: The Stationery Office

Preface

Electricity is one hazard which firefighters will encounter in many and varied operational circumstances.

Its presence, or possible presence, must always be taken into account when making an initial operational risk assessment at an incident.

A knowledge of the basic theory, potential hazards, types of equipment used and procedures to adopt set out this book will assist in the safe conduct of such incidents.

This book replaces:

The Manual of Firemanship Part 6b, Chapter 3 – Electricity and the Fire Service;

Technical Bulletin 1/1978; and

Dear Chief Officer Letters:

5/1989 item C, Annex A and B;
11/1987 item C; and
16/1978.

The Home Office is indebted to all those who have helped, in particular the Electricity Association and its member companies, in the preparation of this work.

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Electricity

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Electricity

Introduction

The presence of an electrical installation at, or near, a fire presents an added risk to firefighters. If the supply can be cut off quickly firefighting can proceed normally, but, if this cannot be done immediately, non-conducting extinguishants usually have to be used.

It was once considered that 'electrical fires' constituted a separate 'fire class' but a little thought will show that any fire involving or started by electrical equipment must be either Class A, B, C or D.

In this book electrical theory is touched upon, but the subject is better dealt with in a textbook specially written for it, and firefighters wishing to be better informed should pursue their studies in that direction.

Electricity distribution and electrical apparatus are discussed and also some types of electrical incidents and how best to tackle them. Incidents involving electricity on railways are, at the time of publication of this book, dealt with in the Manual of Firemanship, Book 4, Part 3. This is to be replaced by a new book, 'Incidents involving Railways', in Volume 2 of the Fire Service Manual.

Reference will be found in the text to an 'Authorised Person'. An 'Authorised Person' is someone from an electrical company with specialist responsibilities related to procedures with live electrical equipment.

At an incident involving electrical equipment which is owned or controlled by an electrical company an 'Authorised Person' is the only person who can confirm that electrical equipment is safe to approach. It is important to liaise with and take the advice of that person at the earliest opportunity.

At an incident involving electrical equipment which is owned or controlled by some other organisation (e.g., a privately owned sub-station in a large factory) then someone from the company with the relevant specialist knowledge should be sought.

'SAFE APPROACH' – Training Video

In 1994 the Electricity Association in conjunction with HM Fire Service Inspectorate, the Fire Service College and the Fire Service, produced a training video 'SAFE APPROACH'.

This video should be seen as a part of an overall training package consisting of the Fire Service Manual, the video and 1(i)(d) visits.

Enquiries regarding the cost of, and how to obtain, the video 'SAFE APPROACH' should be directed to:

The Production Unit
The Fire Service College
Moreton-in-Marsh
Gloucestershire GL56 ORH

Structure of the Electricity Industry

England and Wales

As a result of the privatisation of the electricity industry in England and Wales, the Central Electricity Generating Board's (CEGB) businesses were transferred to four companies. Three of these – National Power plc, PowerGen plc and Nuclear Power plc (the latter later merged with Scottish Nuclear to form British Energy) are engaged mainly in generation. The fourth company, National Grid Company plc is mainly involved in operating the transmission network.

Electricity Supply Companies

There are twelve major Electricity Supply Companies (which are largely regionally based) which jointly own the National Grid Company (NGC). The Electricity Supply Companies operate their own distribution networks which connect consumers in their areas to the National Grid or to local power stations. They buy electricity both from the major electricity generators and independent power producers on the spot market and sell it to their customers over these distribution networks.

Northern Ireland

As a result of privatisation three main electricity generating companies were formed which must sell their output to Northern Ireland Electricity plc which has the monopoly of transmission and distribution in Northern Ireland.

Scotland

As a result of the privatisation of the electricity industry in Scotland three main electricity companies were formed of which two, ScottishPower and

Scottish Hydro-Electric are responsible for the distribution of electricity in Scotland, the third company Scottish Nuclear, later merged with Nuclear Power to form British Energy.

In addition to the major electricity companies there are, throughout the country, a number of smaller generation businesses, for example, industrial companies with on-site generation, rail and tram operators, local combined heat and power schemes, and some privately owned renewable energy schemes.

It should be remembered that the structure of the electricity industry is likely to be subject to change; with changes in both the names and the numbers of companies involved in the industry. See Appendices 3 and 4 for details of the major electricity companies.

The individual Electricity Companies MUST be regarded as the source of authoritative advice in relation to ALL relevant activities within their areas

Chapter 1 – Electricity

1.1 Electrical Units

Electricity, when flowing along a wire (known as a conductor) is called a current, and this is a measure of the number of electrons passing a particular point in a conductor. This rate of flow is measured in units called amperes (symbol A). Pressure must be provided to cause the electrons to flow and this pressure, which may be derived from a number of sources, is termed the applied voltage or electromotive force (EMF). This is measured in volts (symbol V); the greater the applied voltage, the greater the current flowing.

An analogy can be drawn between electricity flowing in a circuit and water flowing through a pipe. In hydraulics, the pipe offers a resistance to the flow of water and this resistance to the passage of water is proportional to the diameter of the pipe.

Similarly with electricity, the conductor offers a resistance to the flow of electrons; the greater the size (diameter) of the conductor the lower the resistance. The resistance of a conductor is measured in ohms (symbol R).

There is a direct relationship between voltage, current and resistance. For example, if a circuit has a resistance (R) of 1 ohm and a voltage (V) of 1 volt is applied at its end, a current (A) of 1 ampere will flow. This fundamental principle is known as Ohm's Law which states:

'the value of a current passing through a conductor is directly proportional to the potential difference between the ends of the conductor, and inversely proportional to the resistance of the conductor'.

This can be expressed mathematically by the following equations:

$$R = \frac{V}{A} \quad \text{or} \quad V = AR$$

1.2 The Resistance of a Circuit

The resistance of a circuit, which is measured in Ohms, depends on a number of factors, namely:

- (i) The length of a conductor.
An increase in length results in an increase in resistance.
- (ii) The cross-sectional area of the conductor.
The greater the cross-sectional area, the lower the resistance.
- (iii) The conductivity of the material used.
Some materials are better conductors than others
(e.g., silver is a better conductor than copper).
- (iv) Temperature.
For most materials, the hotter the material, the greater its resistance.

1.3 Conductors and Insulators

Electricity is always trying to find a path to earth, that is, to escape from its conductor and reach the ground or a conducting path which is connected to the ground. Some materials offer such a high resistance to the flow of electricity that the current cannot force its way along them; they are then said to act as insulators. Other materials offer little resistance and are said to be good conductors; copper and aluminium are two examples of good conduc-

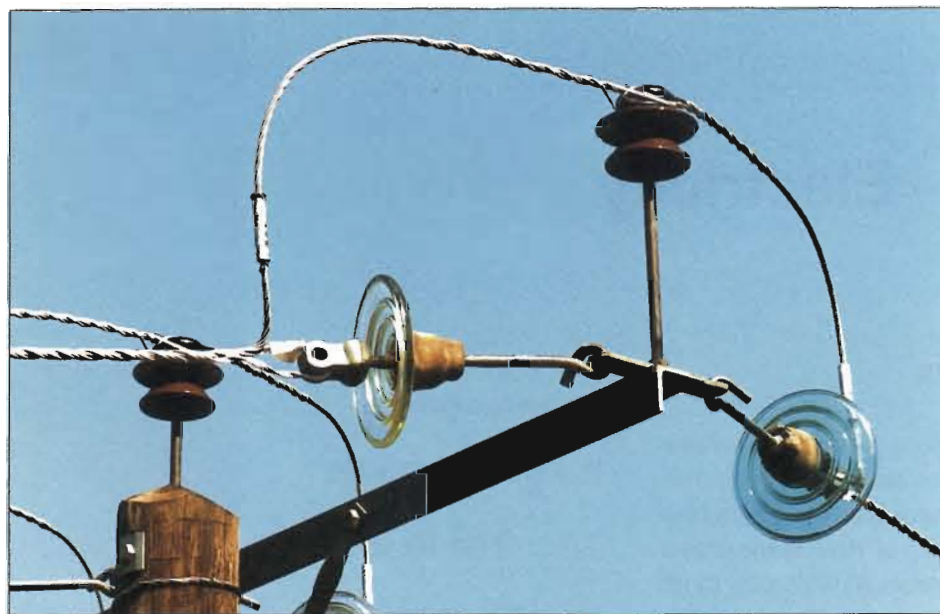


Figure 1.1 11 kV pole showing detail of insulated discs.
(Photo: HM Fire Service Inspectorate)



Figure 1.2 Range of paper insulated 1kV and 11kV distribution cables.
(Photo: Electricity Association)

tors and so are used extensively for electric cables. Water is also a good conductor when impure, so a firefighter with wet clothing or holding wet hose who touches a live conductor could form an electrical path to earth and receive a shock which could be fatal.

In most instances the use of bare wire is impossible and the conductor must be continuously insulated to prevent electrocution on contact. Cables must, in many cases, also have additional coverings to prevent damage to this insulation. For many years vulcanised rubber and oil impregnated

paper were the materials used for insulating, often with lead sheathing and wire-armouring for protection and moisture proofing, these are now likely to be found only in older buildings.

Most insulated cable nowadays is, however, insulated by either an oil impregnated paper or by PVC (polyvinyl chloride) or other plastics such as PCP (polychloroprene) or CSP (chloro-sulphonated polyethylene). These plastics are extremely durable and, whilst not strictly non-flammable, will only burn whilst a source of heat such as a naked flame is continuously applied.



Figure 1.3 Range of pvc insulated 600/1000 volt armoured power cables
(Photo: Electricity Association)



Figure 1.4 11kV XLPE insulated distribution cable.
(Photo: Electricity Association)

It should be kept in mind that **burning plastic covered wire will give off toxic fumes and gases.**

A mineral powder (generally magnesium oxide) within a copper sheathing is also used as an insulating medium for cables which are laid in hot places, such as near furnaces or boilers or in situations where circuit integrity is vital e.g., alarms. These cables are known as MICS (mineral insulated copper-sheathed) or alternatively MICC (mineral insulated copper-clad) cables and are also used in general situations where extra physical protection is required.

When conductors form overhead lines or switch-board connections then insulation is often neither desirable nor appropriate. In such cases arrangements must be made to stop the cables coming into contact with their supporting structures and with each other. This is achieved by the use of insulators which are usually made of porcelain or glass.

1.4 Short Circuits

Whilst air and most other gases are good insulators, electric current can, if the insulation becomes faulty, leak between two conductors or between one conductor and earth. The amount of current leaking depends, among other things, on the voltage, the condition of the insulating material and the distance between the conductors.



Figure 1.5 Miniature Circuit Breaker.
(Photo: HM Fire Service Inspectorate)

If a breakdown occurs in the insulation separating adjacent conductors or a conductor from the earth, what is known as a short circuit takes place. That is, the current, instead of following its normal path, finds a quicker return path. The electrical resistance in such a case is generally negligible, whereupon a heavy current will flow and cause intense local heating combined with overloading of the cables. They may then become dangerously overheated unless the circuit is broken.

Such a breakdown in the insulation may take place in many ways. Insulating material will deteriorate with age or from other causes, and a condition may be reached where their insulating properties are insufficient to prevent a short circuit. The perishing of rubber, is a good example of this, and is one of the reasons PVC has superseded rubber as an insulating medium. Cables or wiring may be subjected to mechanical stress through vibration caused by external influences, whilst dampness is a frequent cause of the breakdown in insulating properties.

Alternatively, excessive heat through external causes e.g., steam pipes, industrial processes for which the system has not been designed, will also lead to rapid deterioration. Furthermore, insulation is often destroyed by nails driven into walls and penetrating the wiring; workers picks, pneumatic drills etc., striking cable runs; abrasion and (although rarely) rodents.

If a breakdown of insulation occurs, excessive current will probably flow through the fault and, if the fuse or circuit breaker fails to operate, overheating will result. For a fire to occur in such circumstances, it is only necessary that there should be combustible material in close proximity to an over-heated wire or a hot spark. Fire can readily be started through a short circuit whether or not a cable is insulated.

1.5 Protective Devices

When an electric current passes along a conductor it generates heat. If the maximum current the conductor is designed to carry is exceeded, either because of excessive load placed on the circuit, or because of a short circuit, overheating will occur and the conductor may become hot enough to ignite the combustible insulation with which it is covered. To prevent this, an electric circuit is fitted with a fuse or circuit breaker to break the circuit in the event of an overload.

(a) Fuses

In its most basic form, a fuse is a short length of wire having a low melting point and forming part of a circuit, the size of the fuse wire being calculated for the normal expected load. If that load is greatly exceeded the passage of the extra current causes the temperature to rise and the fuse wire to melt, breaking the circuit. Because the fuse will

melt at a much lower temperature than that which would result in a dangerous temperature rise in the rest of the circuit, the fuse will act as the weak link in a chain.

(b) Circuit breakers

In the modern consumer unit, fuses may be replaced by miniature circuit breakers (MCB's) which look like an ordinary switch or a push button. They automatically interrupt the circuit if it becomes overloaded or if a fault occurs. Once the cause of the fault or overload has been identified and corrected the MCB can be re-closed and the circuit brought back into service.

In installations of a greater power, the use of fuses and MCB's is impracticable for technical reasons, and automatic circuit breakers, which operate when the current rises to a dangerous level, are installed. Such circuit breakers are designed to operate automatically if a fault occurs. They can be opened manually if necessary, for example to test the mechanism. They are often closed manually or automatically if they open due to a fault, to ascertain whether the overload was of a momentary nature only.

If a line has been accidentally brought down and is lying on the ground, it may not be making sufficient contact with the ground to operate the circuit breaker. Furthermore, the circuit breaker may be closed automatically several times after a period of time to test whether the fault has cleared. This is known as auto-re-closing (see page 14).

Therefore, it should never be assumed that a circuit is dead even when a circuit breaker has operated.

Chapter 2 – Transmission and distribution systems

2.1 Generation

A generator is a machine which produces electricity.

Electricity is generated, transmitted and distributed as alternating current and can be converted to direct current for specific purposes. Direct current flows from the positive to the negative terminal of the conductor. But, with alternating current there is

a rapid change (or alternation) in the direction of flow which occurs many times a second. The number of changes per second is called the frequency and is expressed in so many Hertz (Hz) (cycles per second); this is standardised at 50 Hz in the U.K.

Alternating current is generally used for transmission as the voltage can be increased or decreased according to the requirements by means of apparatus.



Figure 2.1 Turbine at Eggborough Power Station. (Photo: National Power)

tus called a transformer. Alternating current is particularly suitable for transmission over very long distances for which very high voltages are required. This is because if the voltage is increased, the current is reduced and so the equivalent resistance for any given length of conductor passing the same amount of power is less, so enabling smaller conductors to be used.

Electricity is also distributed almost entirely in the form of alternating current which can, if necessary, be converted (or rectified) into direct current for any specialised use.

(a) Alternators

Alternating current generators are called alternators, which in the U.K. are generally driven by steam turbines, although gas turbine, diesel engines or water turbines (in hydro-electric

schemes) may also be used in some power stations. The main generating stations are linked together and to the main centres of consumption by a network of high voltage overhead lines and underground cables generally known as "the grid".

(b) Power stations

Power stations may have outputs as high as 3,890 Megawatts (MW) while individual alternators vary in size between about 1 MW and 660 MW. Generally their energy sources are either hydro (water), fossil fuels (coal, oil or gas), or nuclear fission (uranium).

The main components of nuclear and fossil fuel power stations are fuel storage, steam raising (boiler or reactor) turbo alternators, water cooling, waste disposal, transformation and connection of electricity to the national grid.



Figure 2.2 Drax Power Station. All power stations should have an emergency plan drawn up which the local Fire Brigade should be aware of. (Photo: National Power)

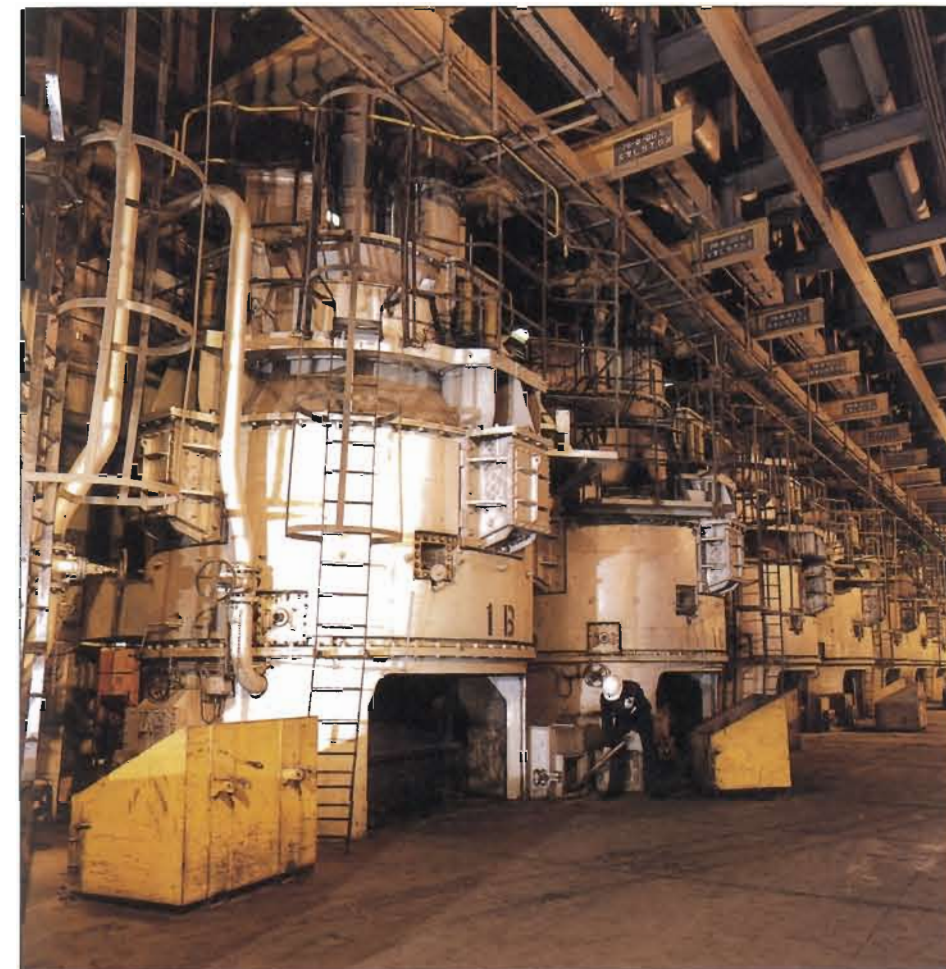


Figure 2.3 Pulverised coal fuel mills at Didcot power station.

(Photo: National Power)



Figure 2.4 Hinkley Point nuclear power station, Somerset. Reactor pile cap.

These are unique to a nuclear power station. It is highly unlikely that fire-fighters would be called to an incident involving a reactor pile cap. Nuclear power stations have especially sophisticated emergency plans.

(Photo: Nuclear Electric)

To reduce fire hazard, areas such as control rooms, switch and transformer rooms, etc., are usually separated from other plant by walls of fire resisting construction and may be equipped with automatic fire extinguishing systems.

The type of building construction varies enormously but modern power stations are generally fire resisting and consist of a steel frame with reinforced concrete walls at low level and metal panel walls above. Roofs are usually of an aluminium construction with bitumen over, and they will usually burn through and partially vent major fires.

Considerable quantities of insulating oil are present in electrical equipment, together with lubricating oil used on turbines and generators which is also stored in large quantities. Most present day stations use hydrogen in closed circuit for cooling the alternators and have hydrogen generating plant, or hydrogen storage in cylinders or banks.

Sulphur Hexafluoride (SF₆)

This gas is used as an insulating and interrupting medium in many types of electrical apparatus throughout the voltage range. The types of equipment within which SF₆ may be found varies from large gas-filled enclosures where entry by personnel is possible, to small items where access to the gas-filled enclosure is not possible, even during maintenance. Because it is heavier than air and will not disperse easily it can be a hazard in confined or low lying areas as it is an asphyxiant.

Under fault conditions toxic and corrosive by-products can be produced, both as a gas and as powdery products. Under catastrophic failure, this powder can be blown over and contaminate the immediate area.

Entry into enclosed contaminated areas should be restricted to personnel wearing breathing apparatus and full protective clothing



Figure 2.5 and 2.6 Sulphur Hexafluoride (SF₆) filled equipment warning signs. BA and full protective equipment must be worn in SF₆ contaminated areas.

(Photo: HM Fire Service Inspectorate)

All power stations in the control of the power generating companies have emergency start-up electricity facilities with gas turbine or diesel engine driven alternators. Some large un-staffed gas turbine generating stations are used for peak demands

on the national grid. Factories and commercial buildings etc., may have small gas turbine or diesel engine alternators. A number of stations using Combined Cycle Gas Turbines (CCGT) have also been built. These stations consist essentially of natural gas and/or oil fired commercial or aero engine generators with the exhaust gases being utilised in conventional steam boilers or, for example, in district heating systems.

2.2 Transmission and Distribution Systems

(a) Transmission and Distribution Network

Figure 2.7 shows the transmission and distribution network in diagrammatic form. It should be noted that transmission lines may be designed for one

particular voltage and yet be operating at a lower one. The majority of overhead transmission lines are double circuit, i.e., a separate circuit is carried on each side of the tower or pylon and these may be energised from separate sources.

(b) Transmission Systems

Most power stations in the United Kingdom feed into the national grid system and the majority of power transmission is by overhead lines. These lines operate at 275 kV and 400 kV. The grid system in England and Wales is under the control of the National Grid Company. In Scotland the grid system is under the control of Scottish Power and Scottish Hydro-electric, whilst in Northern Ireland the grid system is under the control of Northern Ireland Electricity.

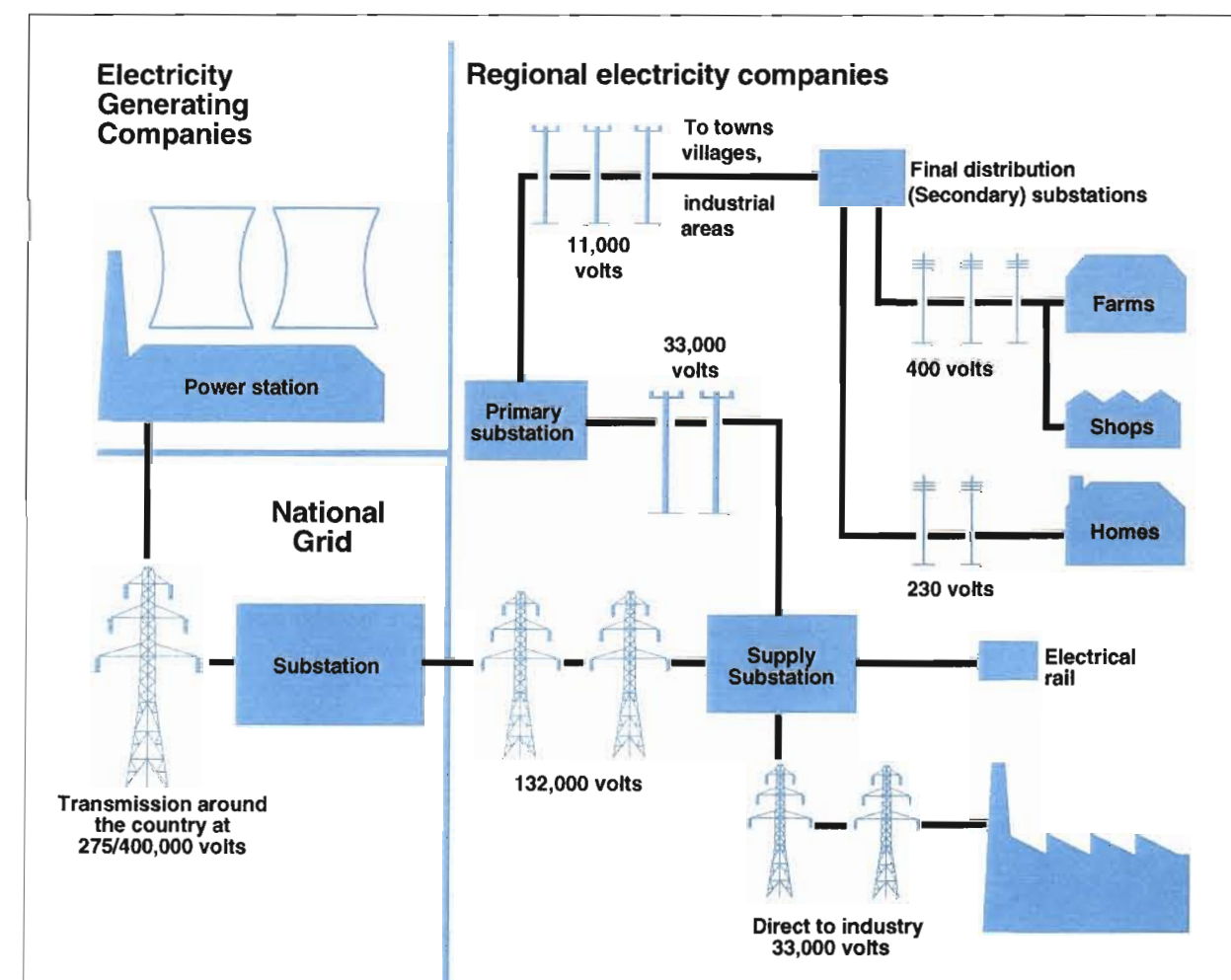


Figure 2.7 Diagram showing the transmission and distribution systems emanating from the national grid down to domestic consumer supplies.

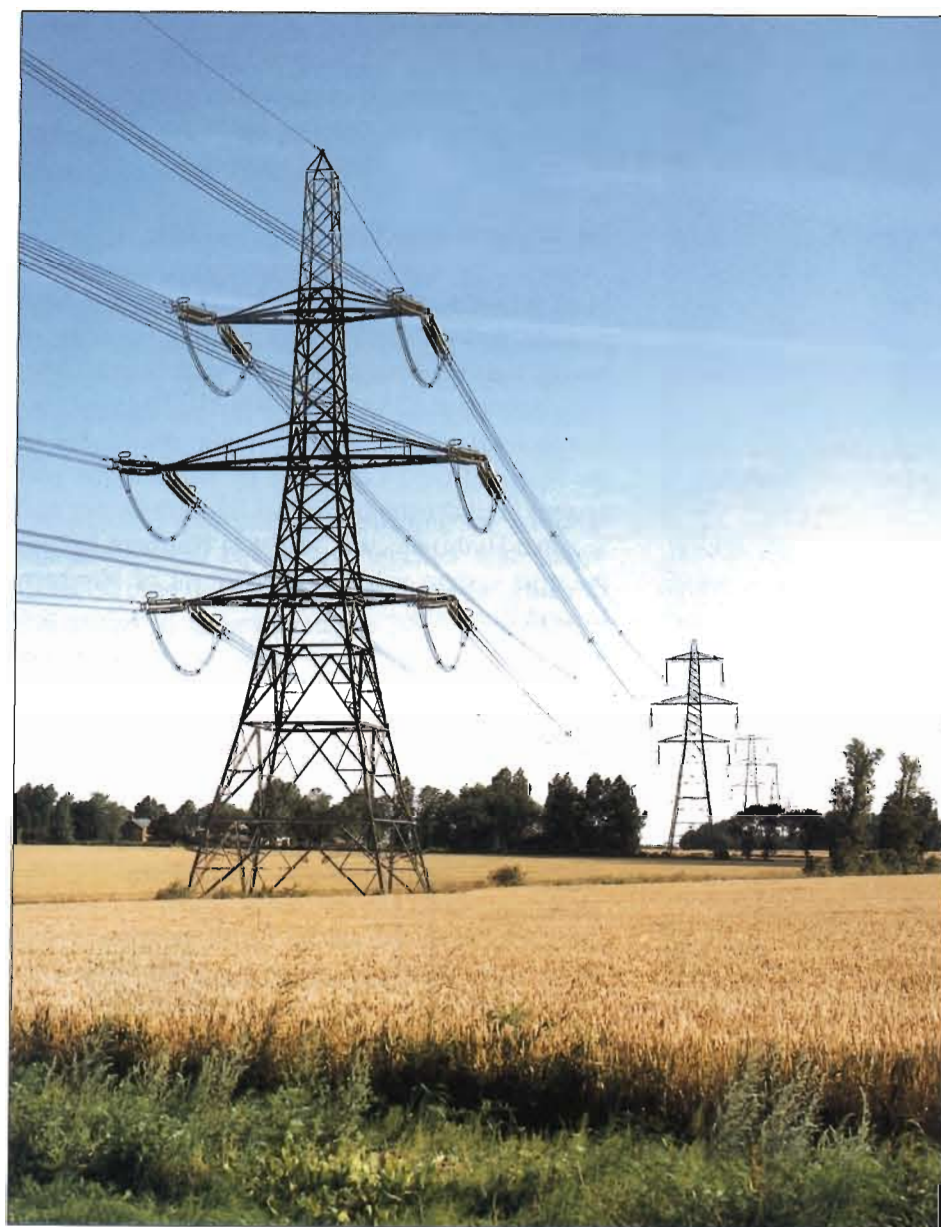


Figure 2.8
Pelham/Waltham Cross
400kV transmission line
showing tension and sus-
pension towers.
(Photo: National Grid Company Ltd)

(c) Distribution Systems

Although high voltages are used to transmit large quantities of power from one part of the country to another, it is necessary to convert to lower voltages before the power can be used by consumers. This is done in stages by means of transformers. Higher voltages are generally reduced to 132 kV, and from 132 kV to 33 kV or 11 kV for large industrial customers and to 'low voltage' at 230/400 volts for commercial and domestic customers.

Voltages are classified as either low voltage or high voltage. The classifications are:

- **Low voltage** – greater than 50 volts but not exceeding 1000 volts ac or 1500 volts dc.
- **High voltage** – anything greater than low voltage i.e., greater than 1000 volts ac or 1500 volts dc.

Firefighters should appreciate that even low voltage systems such as those used in domestic property are high enough to cause severe shock or even death if live conductors are touched. Furthermore, flashovers resulting from insulation failure and/or short circuit can result in severe arcing and burn injuries.

**Voltages over 50 volts a.c.
and currents in excess of
5 milli-amps are considered
dangerous.**

Distribution systems are owned by, and under the control of the Electricity Companies within whose boundaries the systems are situated.

The loading of the transmission system is carried out from Grid Control Centres located in various parts of the country with overall co-ordination at a National Grid Centre. Switching is carried out from the Grid Control Centres. Control of the distribution systems varies from company to company, but, in general, each Company has centre control arrangements supported by local control.

(d) Three-phase system

Alternating current is normally generated by what is known as the three-phase system, that is, a system in which the current flowing is in three interdependent circuits, which are mutually displaced in phase.

For high voltage systems (1 kV upwards) there are normally three conductors or lines between the generator and the transformer. High voltage distribution systems may have three wire or two wire arrangements. When the current is finally reduced below 1 kV a common return conductor (neutral) is introduced.

The voltage between the three phase lines is 400 volts, but the voltage between each phase line and the neutral is 230 volts.

These two voltages are the national declared voltages for normal consumer use.

(e) Safety procedures

The operation and maintenance of the Transmission and Distribution lines is subject to detailed safety procedures and rules. These Safety Rules precisely define who is permitted to work on the system. This authorisation may only relate to a specific part of the system, outside of which that person may not be considered to be 'competent' e.g. only 'Authorised Persons' may isolate lines etc.

The basic principle is that all current-carrying parts of the system are treated as 'live' until they are isolated from the rest of the system, and confirmed to be 'dead' by approved procedures which

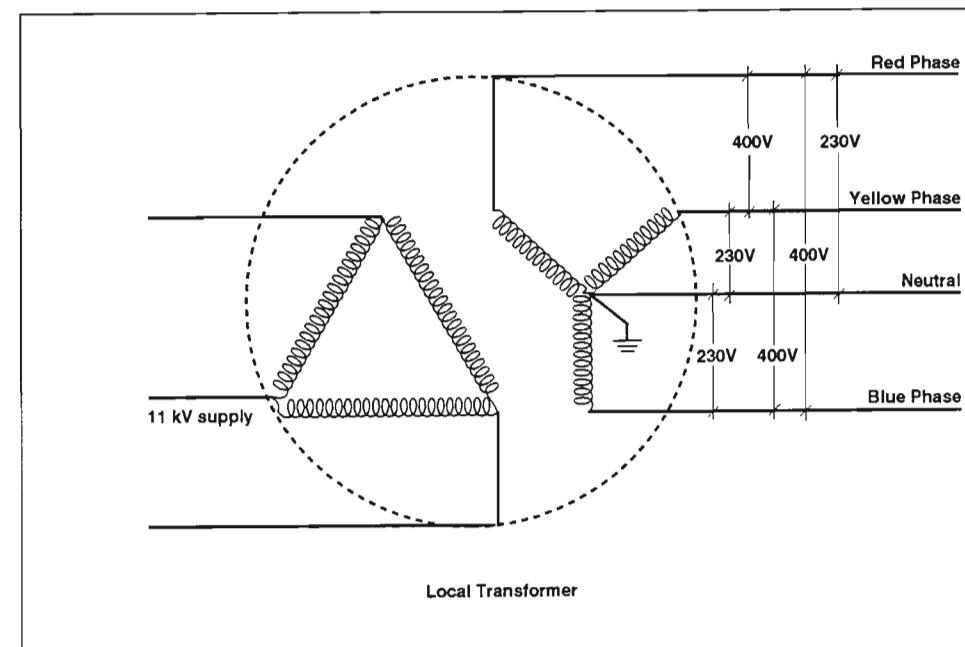


Figure 2.9 The reduction
of high voltage to low
(400/230) voltages in
the three-phase system
shown in diagrammatic
form.

include efficient earthing either at the points of isolation or at either side of the point of work. This confirmation will be given by an 'Authorised Person' from the electricity company.

In normal circumstances no work is allowed until a 'Safety Document' has been issued which clearly states the precautions which must be taken and the area within which work is permitted. In an emergency situation an 'Authorised Person' on site may issue verbal instructions which **MUST** be followed.

These precautions are of the utmost importance when it is appreciated that:

- (i) many lines are automatically controlled and can be switched on remotely;
- (ii) many lines have automatic re-closers so that they are re-energised automatically after a fault;
- (iii) an isolated line parallel to a live line may, if not efficiently earthed, carry a lethal charge; and
- (iv) single circuit isolated lines may be charged due to atmospheric effects and carry lethal voltages.

Electricity Company personnel who are permitted to climb towers or structures carrying live conductors, receive extensive training and are subject to strict safety rules which prohibit work within specified distances of conductors. Any person working on a tower or structure must also be under continual observation by another person on the ground.

Fire Brigade personnel should NEVER climb overhead line supports without the approval of an 'AUTHORISED PERSON' from an Electricity Company

When working on or near a tower or structure carrying live conductors, the minimum safe working distances, as set out on page 42 (see Figure 4.2) apply.

(f) System control

Irrespective of the voltage involved, every part of the system is under control. Within the control network, access to the other control points is usually direct and rapid via telephone or radio. Thus the transmission and the distribution networks are always under the control of a 'Control Person', but local lines at lower voltages may be under the control of local staff on telephone standby in homes and offices. It is vital that there be liaison between the Brigade and the local 'Control Person'. Also, it is important that the fire brigade personnel should have quick access to the control system. To enable this to be done contact telephone numbers are available at all sub-stations and on some structures or pieces of equipment belonging to the Electricity Companies, and certain ex-directory telephone numbers are available at brigade controls for this purpose. These are, of course, only for use in an emergency.

2.3 Substations

(a) Types

The point where electricity is transformed from one voltage to another is known as a substation, and these can vary greatly in size and type. An outdoor distribution substation, for example, may only occupy a space about 1.8 x 1.8 m, whereas a 400 kV switching and transforming substation could cover up to several hectares.

Pole-mounted substations

A pole-mounted rural distribution substation (Figure 2.10) does not usually exceed 11 kV, has a transformer with exposed high voltage terminals and open or enclosed low voltage terminals.

The high voltage supply may be fed to the transformer from overhead or underground cables, and the low voltage local distribution may also be either overhead or underground.

Figure 2.10 Pole Mounted Transformer. High voltage lines are positioned horizontally. Low voltage lines are positioned vertically.

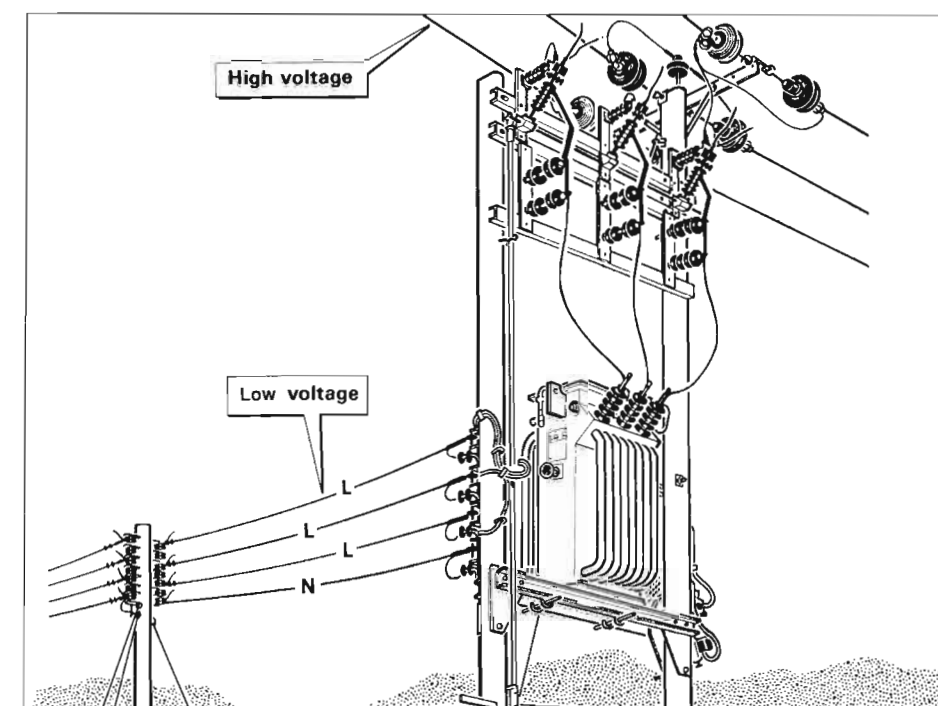


Figure 2.11 Outdoor Distribution 33 kV Primary Substation. Unmanned substations should not be entered unless an 'Authorised Person' is present **EXCEPT** if carrying out a rescue at ground level.

(Photo: National Grid Company Ltd)



Outdoor Distribution Substations

These substations are either one of two types i.e.,

- (i) Primary substations (132 kV/33 kV or 11 kV) which may have exposed live conductors (Figure 2.11) or,
- (ii) Secondary substations (11 kV/400v) which generally consist of a transformer and switch

gear with no accessible live parts, and a low voltage (LV) distribution unit (Figure 2.12).

Secondary substations, which are the most common type of substation, are used to distribute electricity at 230/400 volts to domestic, commercial and light industrial premises.



Figure 2.12 Outdoor Distribution 11kV Secondary Substation, showing (left to right) HV Switchgear, LV Fuse Cabinet and 11 kV/400 V transformer.
(Photo: HM Fire Service Inspectorate)

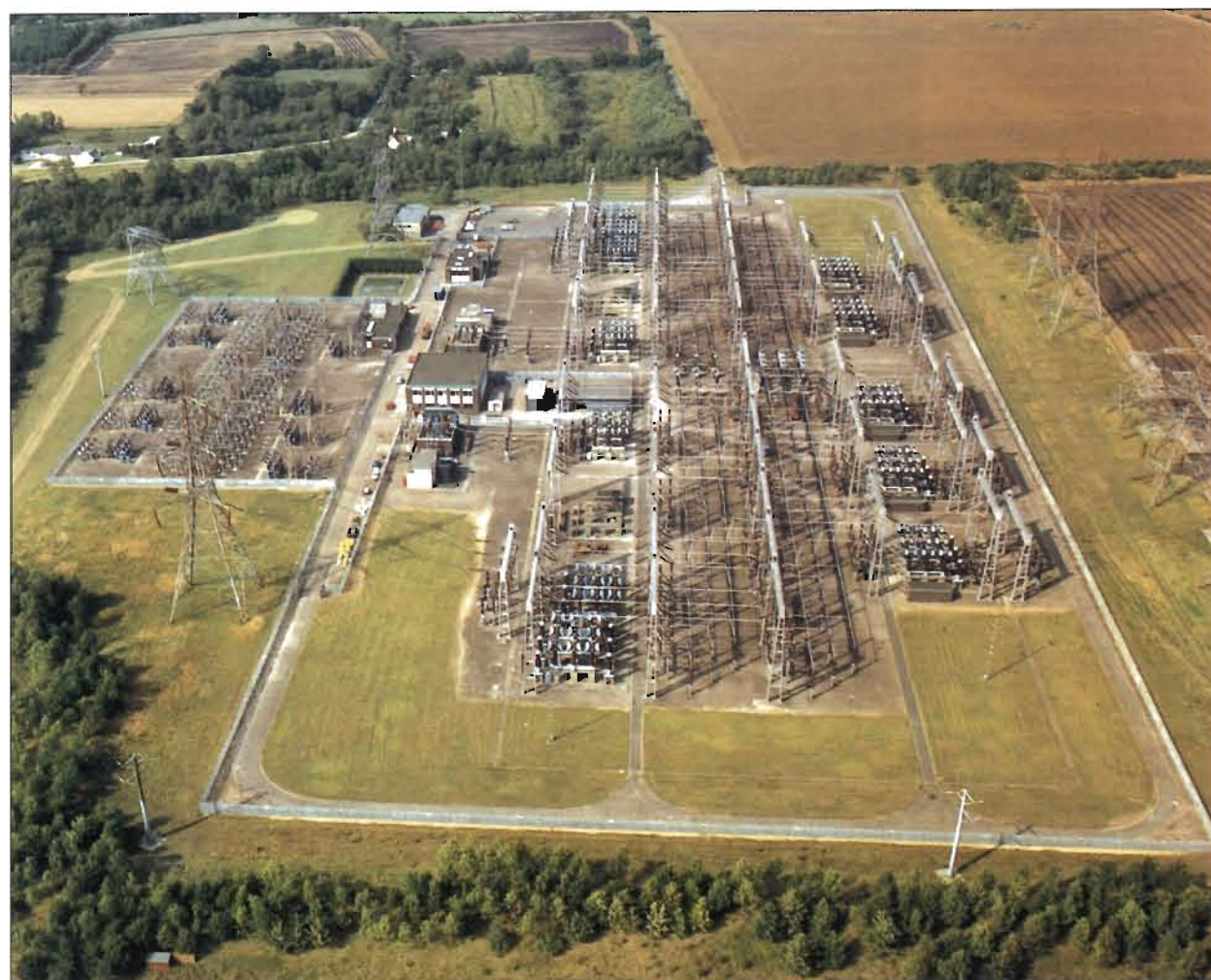


Figure 2.13 Outdoor Grid 400kV Transmission Substation. (Photo: National Grid Company Ltd)

Indoor Distribution Substations

These usually take the form of separate buildings or rooms within or on the roof of larger buildings. They will contain one or more transformers, switch gear and LV distribution units. Voltages do not normally exceed 33 kV.

Outdoor 'grid' substations

These substations (Figure 2.13) vary from single transformer units connected to a single overhead transmission line, to multi-transformer units with several transmission lines. The larger sites may include a control building and voltages may be up to 400 kV.

Indoor 'grid' substations

These are usually found in cities and large developed areas where space is difficult to find. They are, in effect, more compact versions of the outdoor 'grid' substations and may contain enclosed or open type switchgear and bare conductors.

(b) Transformers

The more usual type of transformer consists of insulated copper conductors wound round iron cores, which may be immersed in oil in a tank. In some transformers the oil may be contaminated with Polychlorinated Biphenyl (PCB), and can pose a health and environmental hazard if released (see page 55).



Figure 2.14 'Enclosed' transformers are generally used in urban areas. (Photo: National Power)

In the larger types [Figure 2.15] e.g., those used for voltages down to 33 kV, separate radiators are provided for cooling the large quantities of oil.

When the warm oil has risen to the top of the tank, it flows down the radiator, and the cool oil is then returned to the bottom of the tank. Pumps are sometimes used to assist oil circulation and forced ventilation through the radiators may also be found. In these cases the pumps for oil and air circulation are automatically operated when the temperature of the apparatus reaches a predetermined level.

Smaller transformers e.g., 11 kV and below, have cooling tubes on the outside of the tank instead of

radiators and rely on natural air circulation for cooling. The quantity of oil depends on the size of the transformer and in a large transformer may be as much as 136,000 litres.

Should a transformer sustain damage, either through an internal electrical fault or through some external cause, the oil may be released, possibly at a high temperature or even on fire. Transformers have been known to explode. To prevent escaping oil flowing around other transformers nearby, many modern substations are constructed so that each unit is banded in a separate compound. Some bunds are filled with shingle to a sufficient depth to take the full quantity of oil which could be released. Provision may also be made for draining away the oil from the



Figure 2.15 Typical 'Grid' transformer, showing separate radiators (on right hand side). Note the bund wall.
(Photo: National Grid Company Ltd)



Figure 2.16 11kV/400V Distribution Transformer.
(Photo: HM Fire Service Inspectorate)

compound through a flame trap. Some large transformers, mainly in urban areas and at power stations, are provided with water spray extinguishing systems which automatically operate in the event of fire.

It should always be kept in mind that, although the power to the transformer on fire has been cut off, adjacent transformers could still be 'live' and care should be taken to keep water away from them.

(c) Switchgear and circuit breakers

High voltage

When a switch is opened there is a tendency for the current to arc across the gap and, at high voltages, the distance the arc will jump is considerable. Consequently, high voltage switch gear used for transformers and feeders (see below) are, usually, either filled with oil to quench the arc when the switch is opened or are of the 'Air Blast' type (Figure 2.17). Some switches are automatic in



Figure 2.17 Air blast circuit breaker (switch). (Photo: National Grid Company Ltd)

operation, others are manual and are operated when it is necessary to open or close a circuit.

A circuit breaker is a special type of switch which is normally designed to operate automatically to protect a circuit against overloads or faults.

Those on high voltage circuits which have their contacts immersed in a tank of oil, operate when the current reaches a predetermined level. A very high pressure is set up in the oil when the circuit breaker opens, and the tanks are robustly constructed. A gas vent is also provided to release any explosive gas generated. Gases, such as acetylene, can be produced under fault conditions. If the amount of gas produced is in excess of the designed ventilation provision there can be an explosion risk.

Low voltage

The distribution side of a transformer which supplies low voltage current to consumers is connected to a distribution board. This is a fuse board containing four busbars, one for each of the three phases and one for the neutral. The board is normally contained in a locked metal case if outdoors, but may be open if inside a substation building.

The switching arrangement for isolating transformers from the distribution board is normally through isolating link switches, but sometimes a circuit breaker is connected between the transformer and the busbars. Cartridge type fuses are generally inserted between the busbars and the distribution cables and used to isolate them.

Feeder cable switchgear

The high voltage cables used to connect one substation to another are known as HV feeders, and three types of switch may be employed, namely:

- (i) the automatic oil circuit breaker;
- (ii) an isolator (which is a manually operated oil-immersed switch); or
- (iii) an air break isolator (which is normally mounted outdoors on a pole or gantry and operated at ground level).

Air-blast circuit-breakers operate at pressures up to 60 bar, and when they 'break' they do so with explosive force and produce an extremely loud bang.

(d) Ventilation of substations

When substations are situated in buildings, ventilation is necessary as a considerable amount of heat is generated by transformers, particularly when working at full load. Where forced ventilation is provided, means also exist for shutting off the ventilation in the event of fire. With modern switchgear and protection, the risk is not great, but where oil is used for cooling there is the possibility that this may become ignited.

2.4 Methods of Transmission

The transmission system, both overhead and underground, operates mainly at 400 kV and 275 kV. It transports electricity from power stations to the distribution systems of the Electricity Companies and other suppliers to meet the needs of consumers. The transmission system is interconnected with France by the cross-channel submarine cable link.

(a) Overhead Lines

Transmission overhead lines at 400 kV and 275 kV are supported on large galvanised steel towers and consist of un-insulated aluminium/steel or aluminium alloy stranded conductors. The conductors are insulated from the towers by porcelain or glass insulators.

Most towers carry two circuits with the three phases of each circuit installed in a vertical formation on opposite sides of the towers. An additional conductor, which is an earth wire, connects the peaks of the towers together. Depending on the power transfer of each circuit the phases may have single, twin or quadruple sub-conductors.

Each tower has a unique identification number which is displayed on a notice mounted above an anti-climbing guard which is installed to prevent unauthorised access to the upper sections of the tower. Each circuit also has a unique circuit identification which is a combination of

Figure 2.18 Notice on pylon gives details of owning company, emergency telephone number and tower identification number. These signs are situated above the anti-climbing guard.

(Photo: Electricity Association)

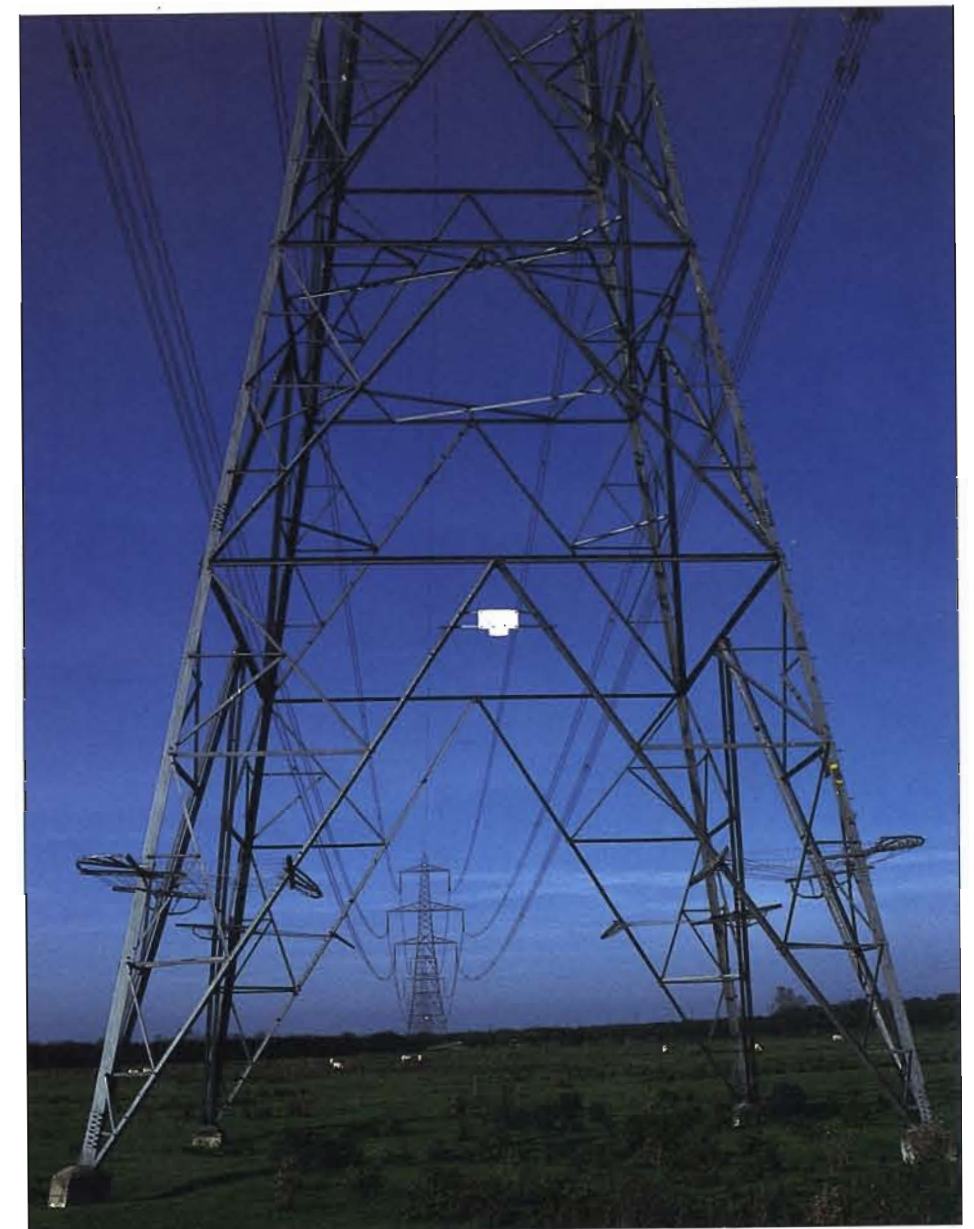


Figure 2.19 Detail of Tower identification signs. Note the emergency telephone call number and the tower identification number.

(Photo: Electricity Association)





Figure 2.20 Pylon. Note the anti-climbing guard and the circuit identification colour code.

(Photo: Electricity Association)

colours or symbols and these are displayed on plates fixed at various points on the legs of the tower.

Wood pole lines operate from low voltage up to 132 kV high voltage. Only high voltage poles are fitted with a danger notice.

(b) Cables

Transmission cables can be up to 150 mm in diameter and may be laid single phase or three phase according to design. If they are single phase they will be laid in the ground in groups of three.

Figure 2.21 Wood poles carrying High Voltage lines carry a danger sign. Low voltage poles do not carry a warning sign.

(Photo: Midlands Electricity)



To maintain the integrity of the insulation the majority are oil filled under pressure; some are gas filled with nitrogen or even contained in a welded steel pipe which is itself filled with nitrogen under pressure.

The power transfer capabilities of transmission cables can give rise to a considerable amount of

heat which is dissipated into the backfill and ground around the cables. To maintain the design rating, some circuits have cooling pipes laid in the ground with the cables. These pipes contain water from either an open pumping system which extracts and returns water to rivers, lakes, etc., or a closed system with towns mains water containing chemicals to prevent corrosion of the water pipes.



Figure 2.22a and 2.22b
Underground cable link
box. 400/230V.
(Photo: HM Fire Service Inspectorate)



The cables are often laid in the public highways or pavements and on some designs, at specific intervals throughout the route, link boxes or pillars will be installed. Link boxes in the carriage-ways are protected by heavy pit covers. On oil-filled cable routes, pressurised oil tanks may also be buried adjacent to the cables.

Transmission cables are usually buried at a depth of approximately 1 metre and are protected by reinforced concrete cable covers imprinted with the words "Danger electricity". If the cables are modern exposed cables with PVC sheaths they will have "Electricity ... volts" imprinted in the sheath.

Cables are often used to interconnect equipment within substations and at larger urban sites these cables may be installed in a network of tunnels, often running for several kilometres under the site.

Fires in these tunnels present several hazards i.e., toxic fumes and thick smoke from burning insulation, cramped conditions, obstructions caused by cables and cable mounts and the presence of large numbers of HV cables, some of which could be exposed and live.

**Entry to these tunnels
and/or firefighting should
NOT be undertaken without
the presence of, and in
consultation with, an
'Authorised Person'.**

Cables are also installed in ducts or tunnels under major roads, motorways and rivers and in disused railway tunnels.

2.5 Methods of Distribution

At a distribution substation, voltage is reduced to its final level of 230/400 volts for use in shops, commercial premises, homes, etc.

From the substation, electricity is distributed to the consumer either by overhead lines, underground cables or by a combination of the two.

Underground systems

The cables which run from the distribution units in the substation are called distributors and each cable either consists of four conductors – one for each of the three phases and one for the neutral, or three conductors – one for each of the three phases.

Sometimes there is a fifth conductor in order to provide a separate control wire for public street lighting.

Underground cables are continuously insulated and in some cases will be armoured.

Overhead systems

Overhead electric lines are normally un-insulated, (it should always be assumed that all wires are un-insulated unless specifically informed otherwise by an Electricity Company official) and they are mostly used in rural or semi-rural areas.

The cables run from the distribution units in the substation to poles carrying the lines or conductors at the start of the overhead distribution system. The phases and the neutral of the cables are connected to the overhead lines or conductors at the top of the pole and consumers' services are tapped at the nearest pole to the premises concerned.

Junction or link boxes

At intervals on underground cables, link boxes (or feeder pillars) may be constructed to interconnect feeders and distributors to smaller cables, to enable cables to be tested and to facilitate inter-connecting or isolating of connections.

These boxes are set in a brick pit below the ground with a cover at pavement or road level for access. There may be several cables entering the box, and they will be connected to one side of a link for each phase. The other side of the link is connected to a busbar, in the same way as in a distribution unit. The box is filled with a bituminous compound, with only the contacts exposed.

In some areas, above-ground kiosks are used instead of under-ground boxes. These kiosks take

the form of steel or glass reinforced fibre (grf) feeder pillars and are used as feeder, disconnection or distribution boxes.

Only 'Authorised Persons' on the staff of the electricity companies, or their authorised agents are permitted to have access to link boxes, feeder pillars or above ground kiosks.

Service cables

From the street distributors, service cables are taken to supply each individual consumer and terminate at a main fuse, or cut out, at the consumers' premises. Apart from the main fuse and meter, the installation is the property of the consumer and therefore varies considerably in type and layout. Details of the wiring of consumers' premises are discussed in Section 3.

Electricity

Chapter

3

Chapter 3 – Internal Distribution

3.1 Single-phase Low Voltage Systems

(a) The service termination

Small consumers, such as domestic premises, are supplied by the Electricity Company with a single phase and earth system.

For new supplies, the electricity companies prefer to install their service terminal equipment in cabinets which are accessible from outside the building. The supply to their cabinet is often through an underground cable, even when the distribution system is on overhead lines. However, underground service cables may also be installed through sealed ducts to service terminal equipment, often called the meter position, within the building.

In older overhead supply situations two service lines are secured to insulators attached to the building, and from these, short lengths of insulated cables are run to the service terminal equipment inside the building. Modern systems use an insulated cable with two concentric cores from the overhead line to the point where it is attached to the building and on to the service terminal equipment.

The electricity company's service terminal equipment should be mounted on fire resistant boards. Both underground and overhead service cables are connected to a cut-out. This consists of a fuse in the live, or phase, conductor to protect the supply cables if severe overloading occurs, and a solid connection (sometimes through a link) in the neutral conductor. The neutral conductor is not fused because it is connected to earth on the electricity company's system and, under normal conditions, is always at, or near, earth potential. If a fuse had been installed in the neutral, and it had operated,

the neutral conductor would become discontinuous and it would be possible for a dangerously high voltage to appear on the consumer's installation.

Finally, from the cut-out, two insulated and sheathed conductors are connected to a meter. There may be more than one meter if different tariffs operate in a particular consumer's premises.

(b) Internal distribution after the meter

For the typical small-consumer type of installation the incoming cables from the meters are connected to one or more consumer units which comprise a double pole main switch and a number of fuses or miniature circuit-breakers. Operation of the main switch will disconnect the installation from the electricity company's supply system, but it must be remembered that the incoming supply from the distribution system will remain live. The fuses or miniature circuit-breakers control the lighting and power circuits in the building.

Socket outlets for power supplies are normally connected to ring circuits in which the conductors are looped from one socket outlet to the next. Both ends of the live conductor loop are connected to the same fuse in the consumer unit. Similarly, both ends of the neutral conductor loop and the circuit protective conductor loop are connected to the neutral and earth blocks respectively. It is common for one ring circuit or main to serve one floor with each subsequent floor being served by a further circuit. In addition it is also common for a further circuit to serve a kitchen area.

Occasionally, old installations may be found with fused neutrals and similarly in older installations it may be found that each socket outlet is fed independently with its own phase and neutral wire from the final distribution fuse board.

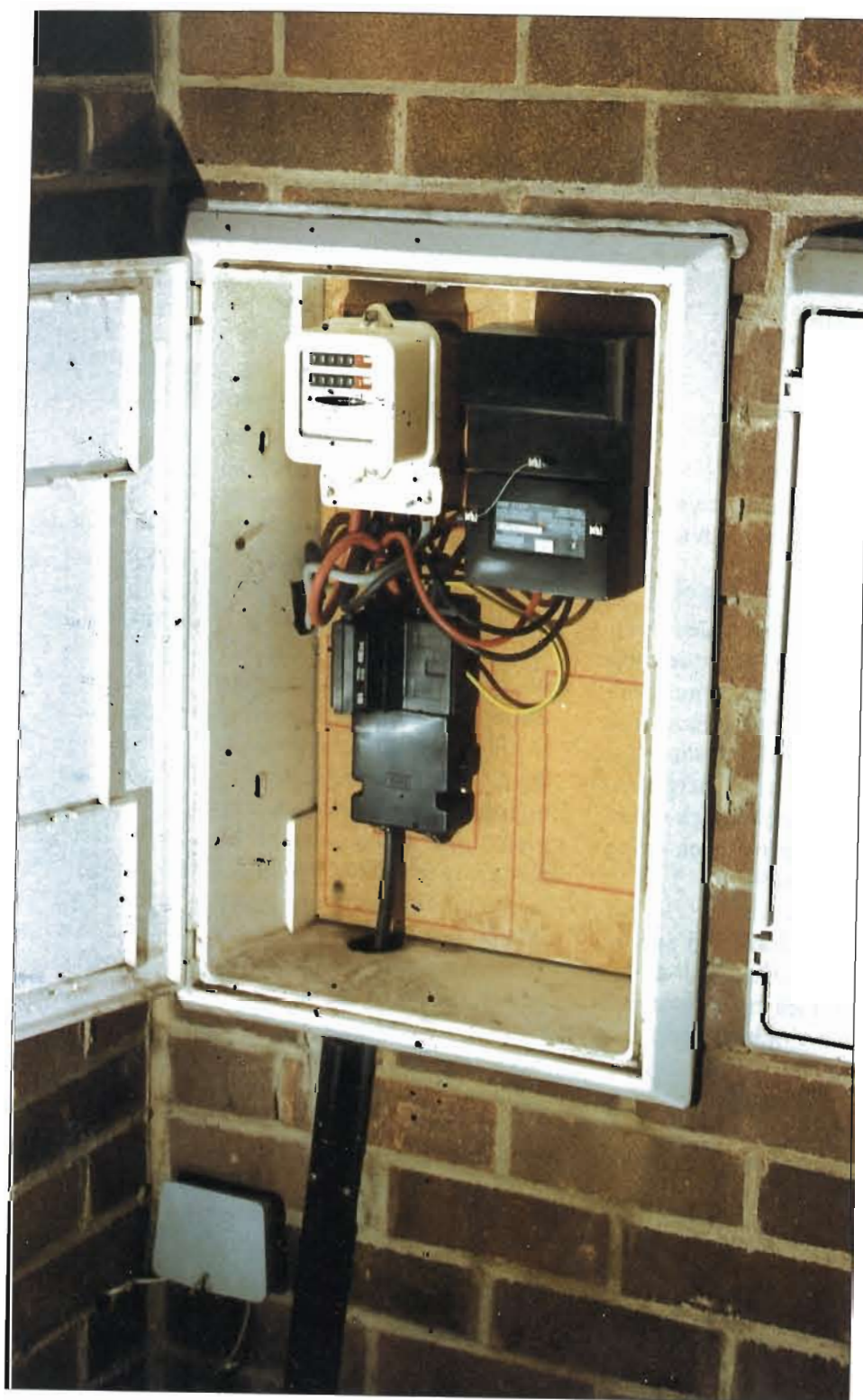


Figure 3.1 A typical external electricity meter cabinet.

(Photo: Electricity Association)

Cooker, immersion heater and shower circuits are separately run and fused in the consumer unit. Lighting circuits also operate on the loop system but are more complex because of the need to provide a switch at a point remote from the light fitting.

There will be great variations in internal wiring arrangements and therefore no wiring convention should be accepted as standard.

3.2 Three-phase Low Voltage Systems

(a) Commercial/Industrial

The electrical demand of commercial or small industrial premises may be such that the electricity company has to provide a three-phase supply. The connection from the distribution system will be similar to a single phase supply, except that the service cable has either three cores and a concentric neutral, or, on older installations, four separate cores encased in a lead sheath. A cut-out with fuses in all three line conductors and a solid neutral is installed. The cut-out is connected to a three-phase

meter by four single core insulated and sheathed conductors. After the meter the supply is fed through a three-phase main switch to a distribution fuse board. In larger installations the main switch may be connected to a bus-bar chamber from which separate single-phase or three-phase circuits controlled by their own switches may be taken to distribution fuse boards at remote parts of the premises.

(b) Residential

A block of flats is often supplied by a single three-phase service cable which terminates in a 'multi-way' cut-out or fuse board (Figures 3.2 and 3.3). A

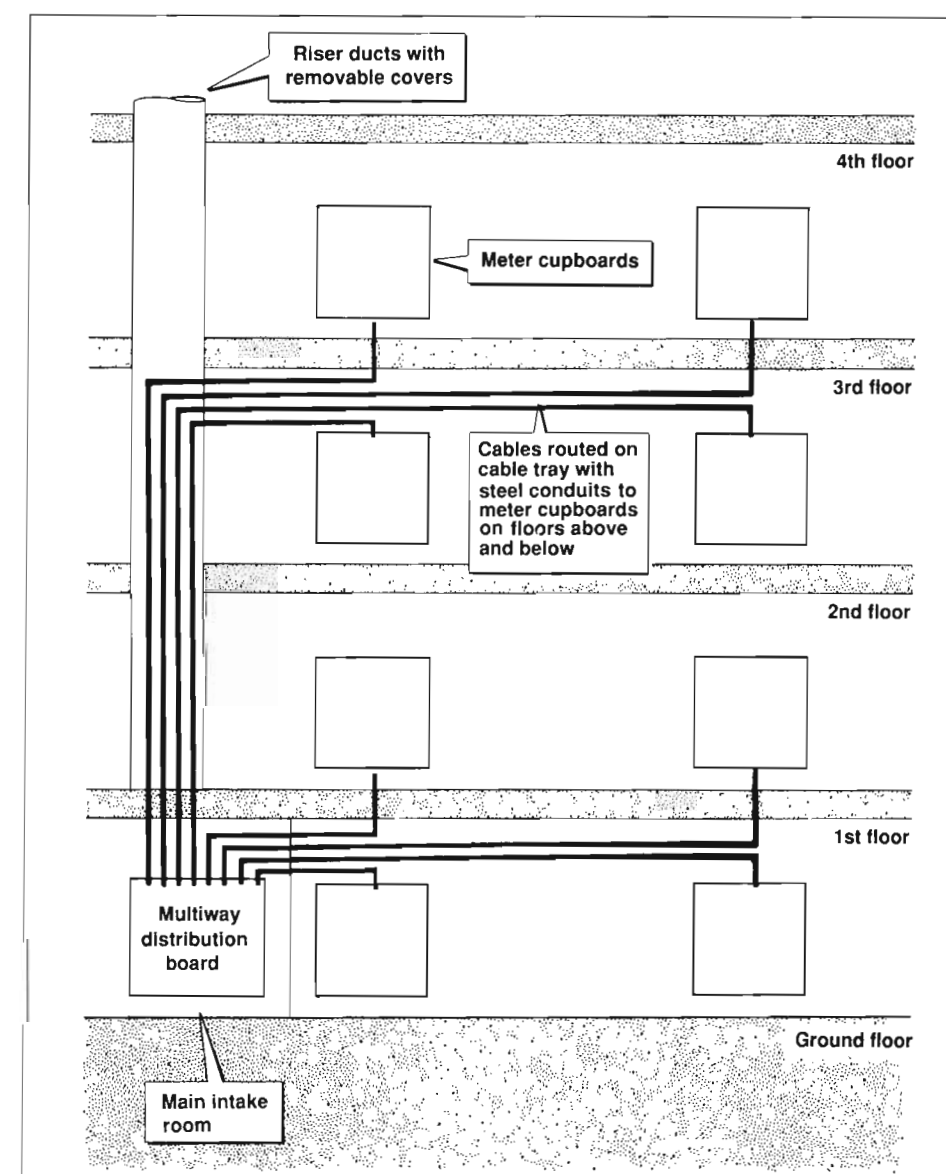


Figure 3.2 Single 3-phase service cable terminating in a Multi-way distribution board.

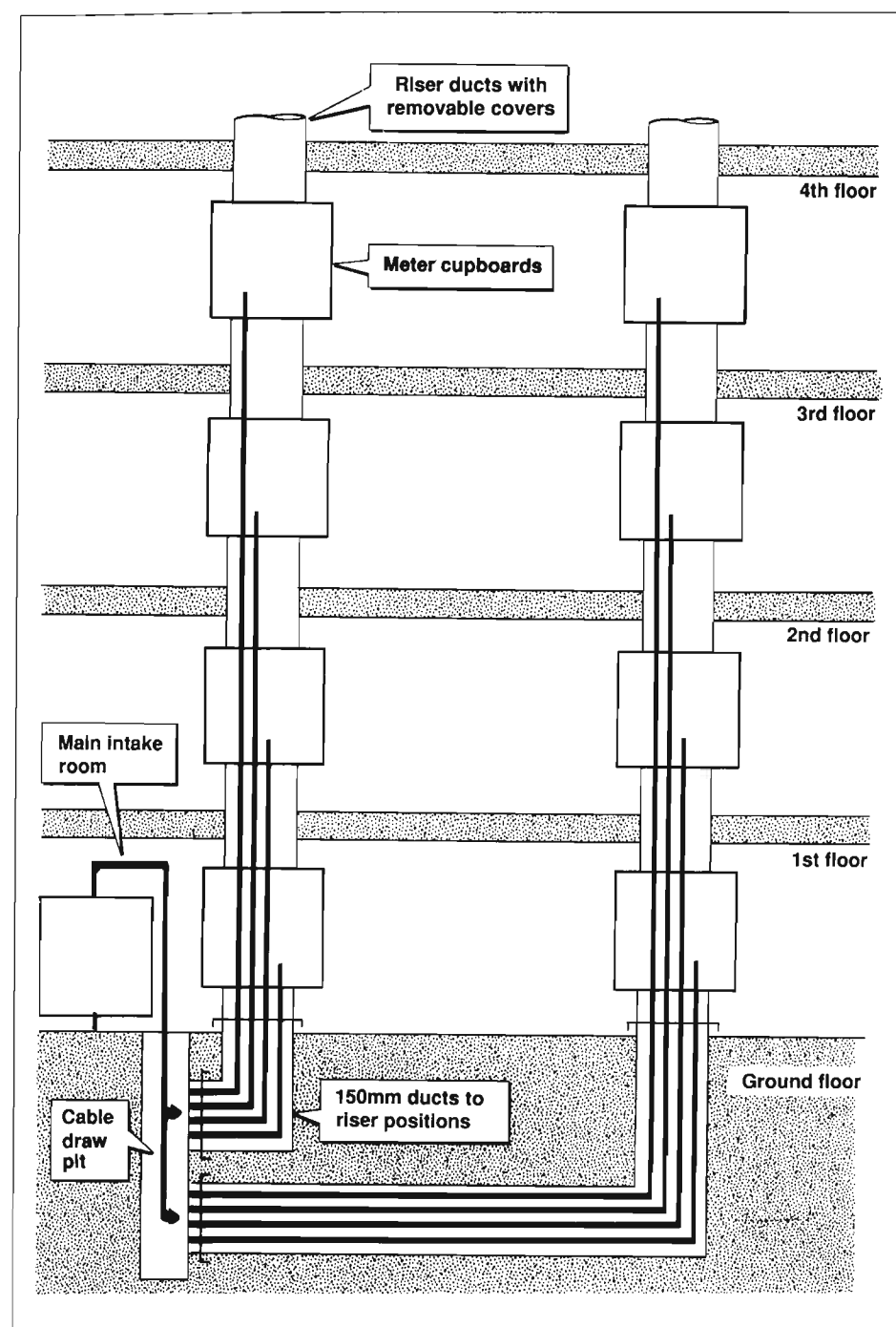


Figure 3.3 Earthing arrangements.

number of separate fuses (usually not more than eight) are connected to each line conductor and single-phase 'rising mains' taken to each flat. If meters are installed in the individual flats the rising main may terminate in another cut-out or a main switch. Alternatively, the meters may all be installed at a single meter position adjacent to the service terminal equipment and the rising main terminates in the consumer unit for each flat.

In some larger blocks there may be more than one service cable. The first three-phase cable may terminate on the ground floor and single-phase rising mains will service the flats on that floor and the next few floors above. Another three-phase cable will be terminated at a higher level to service the flats on that level and the next few floors above, and so on.

In both cases the rising mains will be in service ducts and will outwardly appear the same but it should be remembered that in some large buildings some of the distribution cabling may be three-phase.

For either system the internal distribution for each of the flats will be as previously described.

3.3 Three-phase High Voltage Systems

Where the demand for power is high the electricity company may supply power at high voltage (typically 11 kV) to a substation on the consumers' premises. For a medium sized customer a transformer may be installed at this point to supply a normal three-phase low voltage installation, that is a three-phase four-wire bus-bar with separate sub-circuits connected to it.

Some customers may require a high voltage supply at remote points on the premises. In this case the electricity company will install a high voltage metering circuit-breaker and connect it to the customer's high voltage bus-bar. The customer will then install their own high voltage switchgear to control each high voltage sub-main. Transformer substations are connected to the ends of the sub-mains to give a three-phase low voltage system.

Because the operation of high-voltage switch gear must only be carried out by properly trained, competent personnel, the electricity company will often provide an emergency trip switch to isolate the customer's high voltage system from the electricity company's distribution system. This frequently takes the form of a 'fire alarm' type of switch situated adjacent to the main intake substation or some other conspicuous position: breaking the glass on that switch automatically operates the electricity company's metering circuit-breaker.

3.4 Protection Against Earth Leakage

Electricity can only be safely used if the conductors, or windings of apparatus which carry it, are insulated, not only against contact with other conductors, but also against contact with any metal in which they are encased. Insulation may fail as a result of ageing, moisture, mechanical damage,

heat or corrosion, and precautions have to be taken to protect personnel and installations against consequent damage. Insulation failures could result in severe or fatal shock, or equipment overheating to a sufficient degree to constitute a fire risk.

Electrical systems are designed to provide two lines of defence against electrical shock. The first step is to give protection to the user during the normal working of the installation (e.g., by insulation) and then, in the event of a failure of the first stage, to give protection by automatic disconnection of the supply and earthing.

(a) Earthing

Earthing is the usual safeguard provided to give protection against electric shock. An 'earth' is an electrical connection between a piece of equipment and the general mass of earth such that a fault on that equipment will cause sufficient current to flow to operate the circuit protective devices and, if the equipment has a metal enclosure, to prevent a dangerously high voltage appearing on the casing.

(b) Earthing Arrangements

Fig 3.4 shows four examples of providing an earth connection for electrical circuits (1-4) and an example of providing shock protection by a residual current device (RCD) (5);

- (1) Water pipe earthing: Because of the extensive use of plastic piping, this method is now forbidden as the sole means of earthing in the Institution of Electrical Engineers' (IEE) Wiring Regulations.
- (2) Local earthing (other than water mains pipe): In this system plates, rods or steel frames of buildings are used.
- (3) Cable sheathing and/or armouring: This is the most reliable system available and is used wherever possible, unless the system of supply is as provided in (4) below.
- (4) Protective multiple earthing: In this system the earth-continuity conductor connecting all exposed metal work of the electrical installation is itself connected to the local supply neutral.

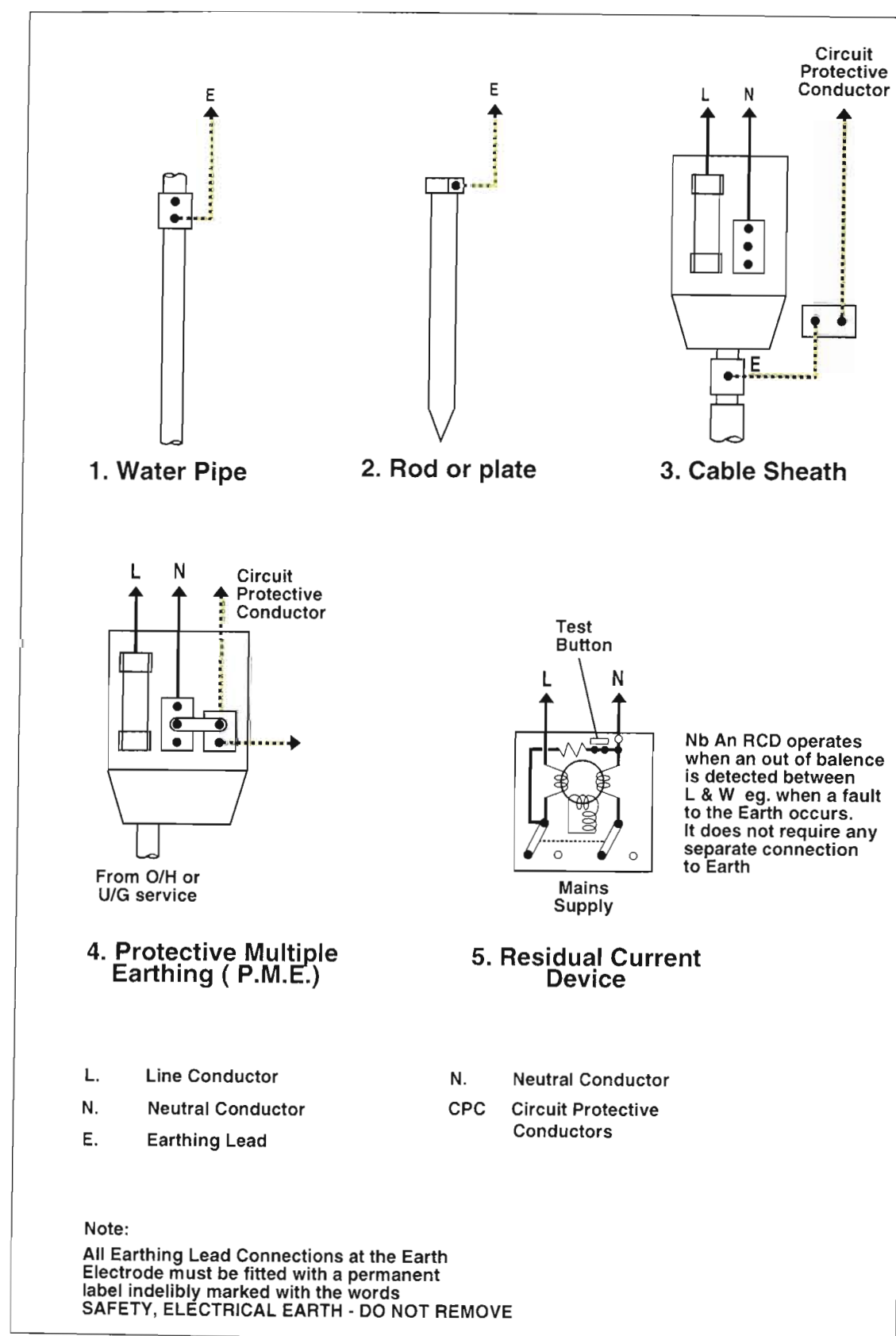


Figure 3.4 Four methods of providing an earth connection for electrical circuits and an example of providing shock protection by a Residual Current Device (RCD).

(5) **Residual Current Devices (RCD)**: These are fittings designed to help prevent electric shock due to faulty electrical appliances or wiring. An RCD can detect changes in the proper flow of electric current and when it does so it disconnects the power supply in milliseconds. This protects against electrocution and other possible damage.

(c) Fires caused by earth faults

Due to some high impedance in the circuit, the current may take an alternative route which can set up arcing which in turn may lead to ignition of adjacent flammable material.

The following are some examples of circumstances where there is a high impedance which prevents the protective gear from operating:

- Failure of insulation allowing a leakage to occur between a phase conductor and an earthing conductor or earthed metal-work, e.g., persistent arcing between a conductor and a conduit;
- Local overheating at a point of high resistance in the earth fault path itself, e.g., at loose or corroded joints in the earth-continuity conductor;
- An earth fault current, unable to dissipate due to high impedance in the earth fault loop, which finds an alternative path to earth by tracking or arcing to adjacent metal-work, e.g., arcing between an earthed conductor (conduit) and a composite gas pipe. This could puncture the gas pipe and cause the escape and ignition of gas.

3.5 Wiring Systems for Consumer Installations

(a) Cables used for wiring

Cables used for wiring can be either single or multi-cored. Modern single cables are PVC covered for general use, but vulcanised rubber installations with tape and braid reinforcement may still be found in old premises.

Lead-alloy sheathed cables are sometimes to be found, but are no longer used for new work.

Mineral-insulated copper-clad cables (MICC) or mineral-insulated copper-sheathed cables (MICS) are used where resistance to fire, damp and mechanical damage is important.

Under the IEE Wiring Regulations both power and lighting circuits require a separate earth-continuity conductor (known as the protective conductor) and this often takes the form of a bare wire inserted between two insulated conductors within the cable.

In MICC or MICS the copper cladding or sheath forms the earth-continuity conductor.

(b) Wiring systems and methods

Most cables can be laid directly and permanently under plaster, but some installations employ conduits through which insulated single-core cables can be threaded. Conduit-carried wiring is often found surface-fixed, especially if the wiring is done after the building is constructed. If non-metallic conduit is used, an earth-continuity conductor is needed.

Another system employs cable trunking, in which large section metal or plastic trunking is used instead of conduit to accommodate large numbers of cables of all types. This is usually a surface system so as to give easy access to cabling for re-arrangement.

In many factories and workshops the plant layout is often subject to modification and such cases the required flexibility of electrical installation is met by cable or busbar trunking systems. These are generally mounted overhead in a steel trunking, and tapped to serve a machine or other apparatus; a lead is taken from the fuse box (or tapping box) to each machine.

The introduction of whole floors given over to computer suites has led to special raised floors being designed in some new buildings. Cables for the electronic equipment are laid either in channelling or directly under the floor and floor mounted sockets, access panels etc., are fitted to enable the systems to be extended, maintained, etc.

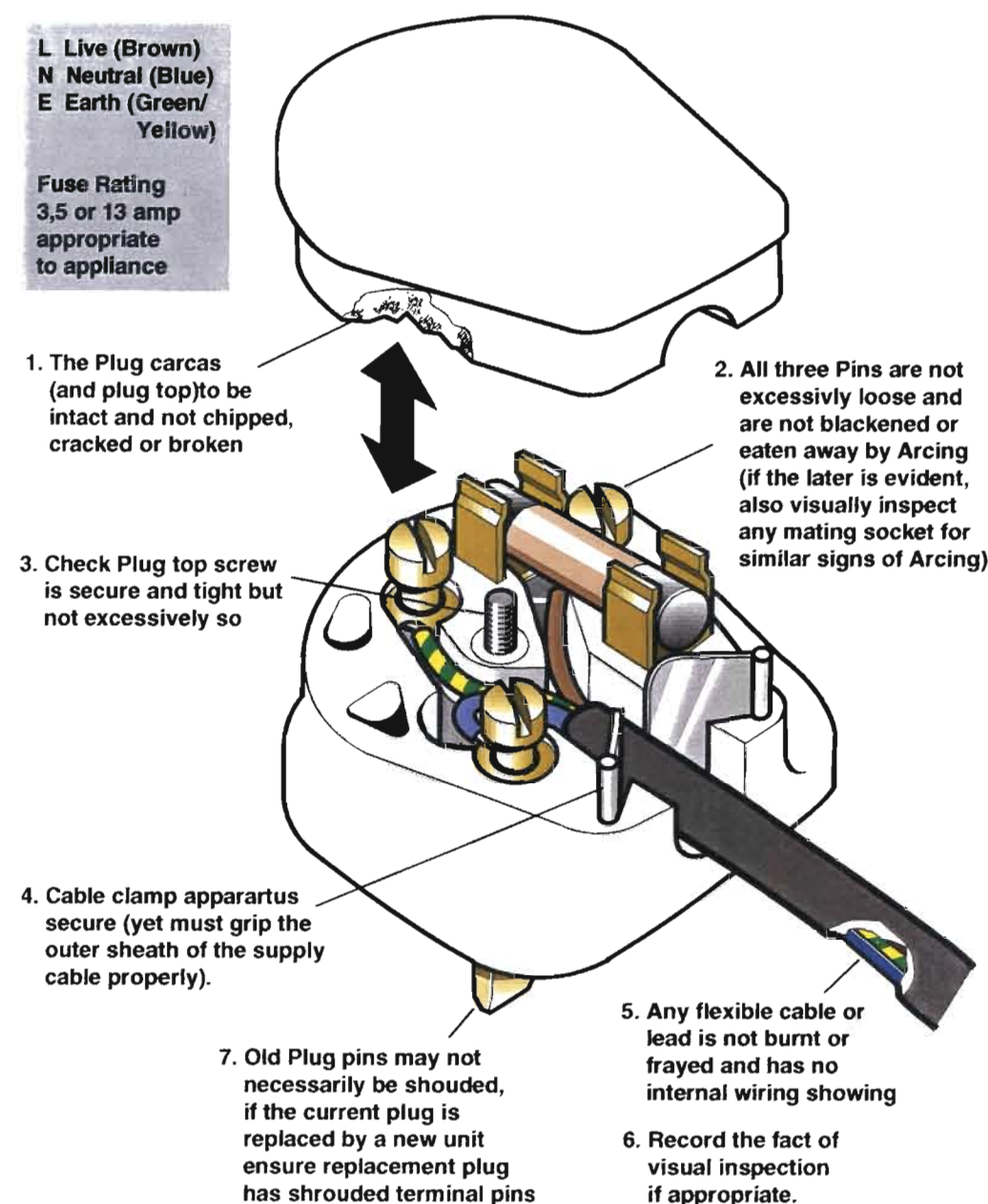
Typical Standard 13 amp Plug.

Illustration depicts an exploded view of a standard rewirable plug AFTER DISCONNECTION FROM THE ELECTRICAL SUPPLY

The following points should be visually checked:

L Live (Brown)
N Neutral (Blue)
E Earth (Green/Yellow)

Fuse Rating
 3,5 or 13 amp
 appropriate
 to appliance



IF ANY DOUBT ABOUT ANY ITEM, DO NOT RE-CONNECT TO ELECTRICAL SUPPLY, INFORM USER OF DEFECT. MARK UP EQUIPMENT AS UNSAFE AND REPORT FACTS TO LINE MANAGEMENT IMMEDIATELY

Figure 3.5 Typical standard 13 amp plug with suggested safety check list.

(c) Flexible wiring

The most common type of flex consists of two or three separate conductors, each with one or two layers of coloured rubber or PVC insulation, finished off with either a PVC or rubber sheath, or in older installations, with silk or cotton.

Prior to November 1970 the colour coding for electric flex had been:

- red – live conductor;
- black – neutral; and
- green – earth.

The current UK colour coding for flexible cables connecting domestic appliances is:

- brown – for the live conductor;
- blue – for the neutral; and
- green and yellow – for the earth (the protective conductor).

3.6 Electric Lighting

There are three main types of electric lighting in use:

- (i) incandescent lamps;
- (ii) vapour lamps;
- (iii) luminous discharge lamps.

(a) Incandescent lamps

The incandescent lamp is the most commonly used form of electric lighting. The current passes through a fine high-resistance wire filament, raising it to white heat. The filament is enclosed in a glass bulb which is generally filled with an inert gas.

(b) Vapour lamps

These lamps do not have a filament but instead have a small quantity of mercury or sodium con-

tained in a gas-filled quartz tube enclosed in an evacuated glass bulb. When the current is turned on, the mercury or sodium is heated, vaporises and the current passing through the vapour causes it to glow. The colour of the light depends on the materials used; mercury gives a bluish-green light and sodium an orange-yellow light.

Normal voltages can be employed for these lamps, but each must be fitted with a choke and capacitor to limit the current passing. The choke and capacitor are usually integral with or close to the lamp-holder.

A modified form of mercury vapour lamp is the fluorescent tube, which is in wide use for lighting purposes. In it, ultra-violet light emitted by the mercury vapour strikes a thin layer of fluorescent material deposited on the inside of the tube and causes it to emit light.

(c) Luminous discharge lamps

When a high voltage current is passed through a tube containing certain gases at very low pressures, the gas becomes luminous and emits a wavelength of a colour which depends on the gas in use.

For example, neon gives a red light, carbon dioxide white and hydrogen green. Because the tubes can be bent into a variety of shapes, they are widely used for advertising purposes on the front of buildings and in shop windows.

These tubes work at 3,000 volts, or more, depending on the length of the tube, transformers being employed to step-up the voltage to the required figure. The wiring therefore constitutes a serious hazard to firefighters, since it may run in many directions over the face of a building against which it may be necessary to pitch a ladder. The transformers, which are usually about 300–380mm square, are mounted close to the discharge tubes and may be in considerable numbers, depending on the length of tubing to be lit. Thus, the average sign for a cinema or theatre may require twenty or more such transformers.



Figure 3.6 'Fireman's switch'.
(Photo: Crown copyright)

(d) 'Fireman's switch'

The IEE Wiring Regulations (which are also issued as British Standard BS 7671) require that all such installations either inside or outside a building must be provided with an isolation switch for use by firefighters. In the regulations this isolation switch is called a 'fireman's switch'. (Figure 3.6)

For an exterior installation the switch will normally be mounted:

- on the fascia of the building out of reach of the public but accessible to the fire brigade; or
- clearly distinguishable notices will identify the location of the switch and the equipment it controls.

Note: In the IEE Wiring Regulations installations in arcades and malls are considered to be exterior.

For an interior installation the switch will normally be in the main entrance to the building.

The switch is installed in the low voltage circuit and cuts off the supply to the transformer(s). Before pitching a ladder against a building on which luminous discharge signs are fitted or working in the vicinity of such signs, either inside or outside a building, the circuits should be isolated by pushing the switch upwards.

Electricity

Chapter

4

Chapter 4 – Electrical Hazards and Safeguards

(a) Electrical Causes of fire

The majority of fires of electrical origin occur due to poor installation, poor or lack of maintenance or the mis-use of electrical systems and apparatus. Electricity is capable of igniting insulation or other combustible material if the power is misused, equipment or cables are overloaded or are not properly insulated and maintained. The most common electrical causes of fires are:

- (i) short circuits caused by insulation failure or during work on an installation;
- (ii) overheating of cables and equipment due to overloading, lack of adequate ventilation or high resistance joints;
- (iii) the ignition of flammable gases, vapours or dusts by sparks or heat generated by electrical equipment;
- (iv) the ignition of combustible substances by electro-static discharges.

(b) Prevention of Electrical Causes of Fire

There is always a possibility that fires will occur due to accidents whilst people are working on electrical systems. With the exception of such incidents the incidence of fires of electrical origin can be reduced by:

- (i) the correct choice of equipment;
- (ii) a well engineered design, with particular attention paid to the electrical protection systems provided;
- (iii) good installation practice;

- (iv) regular preventive maintenance utilising good working practices.

The 'Regulations of Electrical Installations' published by the Institution of Electrical Engineers is the code of practice for the majority of installations operating at 230 and 400 volts in the U.K.

The design and maintenance of systems operating at higher voltage should only be carried out by organisations having the necessary knowledge and expertise.

A number of British Standard Codes of Practice have been published which deal with the maintenance of switchgear from low voltages to the highest voltages found on the Grid System.

(c) Preventive measures in or near Flammable Gases or Vapours

Where flammable gases or vapours may be present particular care is necessary in the selection, installation and maintenance of electrical equipment. A number of types of protection have been developed both for electrical equipment and tools used in areas where flammable gases and vapours may be present. These are:

- (i) Intrinsically safe equipment;
- (ii) Flameproof equipment;
- (iii) Increased safety equipment;
- (iv) Pressurised equipment;
- (v) Non-sparking equipment;
- (vi) Oil or sand filled equipment;
- (vii) Specially protected equipment.

To assist in deciding which type or types of equipment should be used, the areas where flammable gases or vapours may be present have been divided into zones. The safe use of electrical equipment in potentially flammable atmospheres depends not only on the correct choice of equipment for the zonal classification concerned, but also on the way it is installed, the type of cabling system used and its maintenance.

At an incident, as far as firefighters are concerned, the zonal classification is not an important issue. Any indication of flammable gases or vapours will demand the use of intrinsically safe and non-sparking equipment and tools.

(d) Dusts

Combustible dusts may be ignited not only by sparks from electrical equipment but also from hot surfaces on such equipment. Overheating can also be caused by the heat insulating properties of the dust. The selection of suitable electrical equipment, together with good 'housekeeping' practices will reduce the likelihood of electrical equipment causing a dust explosion.

When firefighters are working in dust laden atmospheres precautions should be taken to remove the possibility of sparks igniting the dust. Non-sparking equipment and tools will remove the likelihood of ignition by sparking. In addition, the use of light water sprays will help to settle airborne dust and their use should be considered with the obvious thought being paid to the possible water damage which could occur.

4.1 Static Electricity

Static electricity is probably best known for its appearance as lightning which has been known to cause a number of fires each year. It is probable that some fires are also due to other forms of static electricity. It is impossible to prevent the formation of static electricity, but it presents no problems if it is conducted to earth before it has time to build up a charge sufficient to cause sparking. Precautions taken against static electricity are normally based on this principle.

Friction between two non-conducting surfaces is a

ready cause of static electricity. For practical purposes, it is usually associated with substances which, whilst non-conductors, are also flammable. Thus, if petrol (a non-conducting liquid) is allowed to emerge as a jet from a nozzle, the nozzle can rapidly become charged with static electricity and, unless a path is provided to conduct the charge to earth, a point is reached where the insulating property of the surrounding air breaks down and a spark occurs which could ignite the petrol vapour.

In the case of road tankers, conductive rubber tyres are normally fitted and special arrangements are made to provide a path to earth when loading or unloading.

Non-flammable liquids and vapours will also build up charges of static electricity under suitable conditions. For example, escaping steam from a fractured line or oil refining processes could build up a charge on the plant itself, and special precautions are taken to prevent this charge accumulating. Under appropriate conditions a static charge can be built up on vehicles or equipment fitted with rubber tyres e.g., a number of fires in hospital operating theatres have been caused by static electricity, generated by the movement of the rubber tyres on theatre trolleys, igniting ether or other flammable gases present. Either conducting rubber tyres, a trailing chain or conducting floors are used to lessen the danger. Oxygen enriched atmospheres which occur, for example, in hospitals and some industrial plants and/or processes, will also increase the risk of fire posed by static electricity.

In industry the passage of belting over pulleys is a frequent cause of static electricity. Where there is no possibility of fire risk, such charges may be allowed to dissipate naturally but, where there is a possibility of flammable vapours or dust, efficient means of earthing should be provided.

4.2 Electric Shock

If a firefighter comes into proximity with a live circuit, (direct contact is not necessary as electricity can 'jump') they may receive an electric shock which could be fatal. Other dangerous effects which may occur are paralysis, fibrillation of the heart and cardiac arrest.

It cannot be too strongly emphasised that if it is known, or suspected, that an unconscious person has suffered an electric shock, resuscitation should always be applied, and will often be successful.

The effect of electricity on the human body can vary greatly in different persons and depends upon a number of factors including for example, the voltage of the supply and the path it takes through the body.

The immediate effect of an alternating current is to cause the muscles to contract involuntarily. If an a.c. conductor is, inadvertently, grasped it may be impossible to let go until the current is switched off.

Although at the same current d.c. will have a less severe effect than a.c. it must always be remembered that both direct current and alternating current can be fatal.

Irrespective of whether a.c. or d.c. current is involved in an incident, there is also the possibility of indirect effects; for example, a shock received by a person when climbing a ladder may cause them to fall and sustain injury.

As stated above it is not necessary to touch one of the conductors of a circuit to receive a shock as electricity can 'jump' across a gap if the clearance is not great enough and any conductive material, even though not in direct contact, may be electrified. This distance will vary depending upon voltage and weather conditions.

The principal dangers to a firefighter lie:

- (i) in unwittingly, in the dark or smoke, touching a conductor which has been displaced by the fire or which has electrified other conducting material; and
- (ii) in directing a jet of water or foam on to live electrical equipment.

When standing in water the danger from touching an electrical circuit is greatly increased. Even when wearing a non-conductive helmet, damp and perspiration under the helmet, combined with its

wet exterior, tends to provide a path for a current through the body.

Risk of injury due to touching live wiring or electrical material may be greatly reduced by observing the following simple precautions:

- It is dangerous to attempt to touch any wires or electrical equipment except with the necessary safeguards, e.g., suitably rated rubber gloves, until it is certain that the circuit has been rendered dead.
- All switches in a building which has been damaged should be treated with caution. It is always wise to operate them with an insulated, dry object.
- If it is necessary to touch anything in a damaged building, initially, only the back of the hand should be used. If it is live, the shock will then throw the hand clear.

In proximity to electrified railways, or any other equipment using electricity, firefighters should remember that fire damage to cables and subsequent use of water or foam has been known to leave an electrically charged path some distance from the equipment.

4.3 Safe Approach Distances

Whenever people are in the vicinity of bare, live electrical equipment there is a risk of shock and/or arcing from the equipment to those people, or from any conductive equipment they may be in contact with. To minimise this risk it is always desirable to maintain the maximum practicable distance at all times between any person and any item of live electrical equipment.

Under normal circumstances the presence of fences and/or barriers, or the suspension of live conductors on wooden or metal towers (having a ground clearances of about 5-7 metres), provides adequate clearance to ensure that electric shock or arcing do not occur.

However, it is often necessary for firefighters to work, or use equipment under conditions which are abnormal, in the vicinity of electrical equipment.

In such circumstances additional safety precautions/considerations are necessary.

Any actions which reduce the normal safety distances between personnel, or any equipment they are using, and live electrical equipment should only be carried out following close liaison with an "Authorised Person" of the Electricity Company.

(a) Using Ladders and Aerial Appliances

Substations

Such items of equipment should NEVER be used in or adjacent to Power or Sub Stations without an assurance from an "Authorised Person" of the Electricity Company that it is safe to do so.

Overhead lines

There will be other occasions when, as part of fire-fighting or rescue operations, it is necessary to use ladders or aerial appliances in the vicinity of overhead lines. In such circumstances unless the line can be **definitely** identified as low voltage it must be assumed to be high voltage (i.e., over 1000V and up to 400kV) and no part of any ladder, person or aerial appliance should ever be closer than 10 metres to the line.

Due allowance should be made for the knuckle on HP's.

Firefighters should bear in mind that in high wind conditions, both the cables and the fire service equipment may be oscillating and allowances should be made for that and the safe approach distance increased as necessary.

Training

When training and using ladders or aerial appliances, then the safe approach distance should be doubled to 20 metres.

(b) Working in Dense Smoke

A further possible hazard to firefighters exists when operating under, or in the near vicinity of, overhead power lines and dealing with a fire producing dense smoke or with flames rising close to the conductors.

Under such circumstances there is a danger of an electrical flash-over from a conductor to earth/ground or adjacent structures, trees or Fire Brigade equipment. This phenomenon can occur in both urban and rural areas and particularly from fires

involving smoke with a large carbon content e.g., rubber tyres, certain types of plastics, forest and heath fires.

The flashover hazard applies particularly to higher voltages e.g., 400 kV, 275 kV and 132 kV overhead power lines. However, as it is often not possible to positively identify the voltage carried by a conductor, all high voltage overhead lines should be assumed to be capable of creating this flashover situation.

In conditions of dense smoke or when flames are approaching the conductors, firefighters should avoid positioning themselves or their equipment anywhere within a 'corridor' 10 metres either side of the overhead power line (measured along the ground).

It is also possible for this flashover hazard to be present with ground or near ground installations and in the absence of definite information and advice from an "Authorised Person" of the Electricity Company, the same clear 10 metre corridor should be maintained around any live conductor.

(c) The Use of Water

Water is a conductor of electricity and there are specific safety considerations related to the use of water or foam in the vicinity of live electrical equipment.

Experimental work has been done to establish the leakage current which passes along a jet of water from a live conductor to the branch fitted with a variety of sizes of nozzle.

The results of the experiments produced a series of theoretical distances (between a live conductor and a nozzle) at which a pre-determined current would pass along the water stream to the firefighter holding the branch. The variations in the distances determined, produced two important facts for the firefighter:

- The risk of electric shock increases with the increase in nozzle size (at the same distance).
- Water in the form of droplets is less conduc-

tive than a solid jet and therefore sprays are safer than jets.

It has already been pointed out that it is not possible for a firefighter to positively identify the voltage rating of a conductor. In the absence of information and advice from an "Authorised Person" all high voltage conductors should be assumed to be live at the maximum voltage i.e., 400 kV.

A corridor of 20 metres either side of, or around, the live conductor should be maintained and no hand-held firefighting branch should be allowed within that corridor.

If ground monitors or aerial appliances are in use with large diameter nozzles (i.e., greater than 20mm) then a corridor of 30 metres either side or around the conductor should be maintained and no such large diameter nozzle should be allowed within that corridor.

(d) The Use of Foam

There is little practical information on the conductivity of foam jets and sprays.

In the absence of specific data, foam should be applied with caution and the same minimum approach distances should be employed wherever possible.

(e) Explosion Risk

Oil filled transformers and switch gear have a further additional hazard of a possible catastrophic explosive failure with the resultant release of hot or burning oil over a considerable distance.

The safe approach distances specified will help to avoid injury to firefighters should such a failure occur.

The following points should always be kept in mind:

- Water or foam should never be directly aimed onto live electrical equipment.
- When working near to electricity, sprays are safer than jets and smaller nozzle sizes are safer than large nozzle sizes.

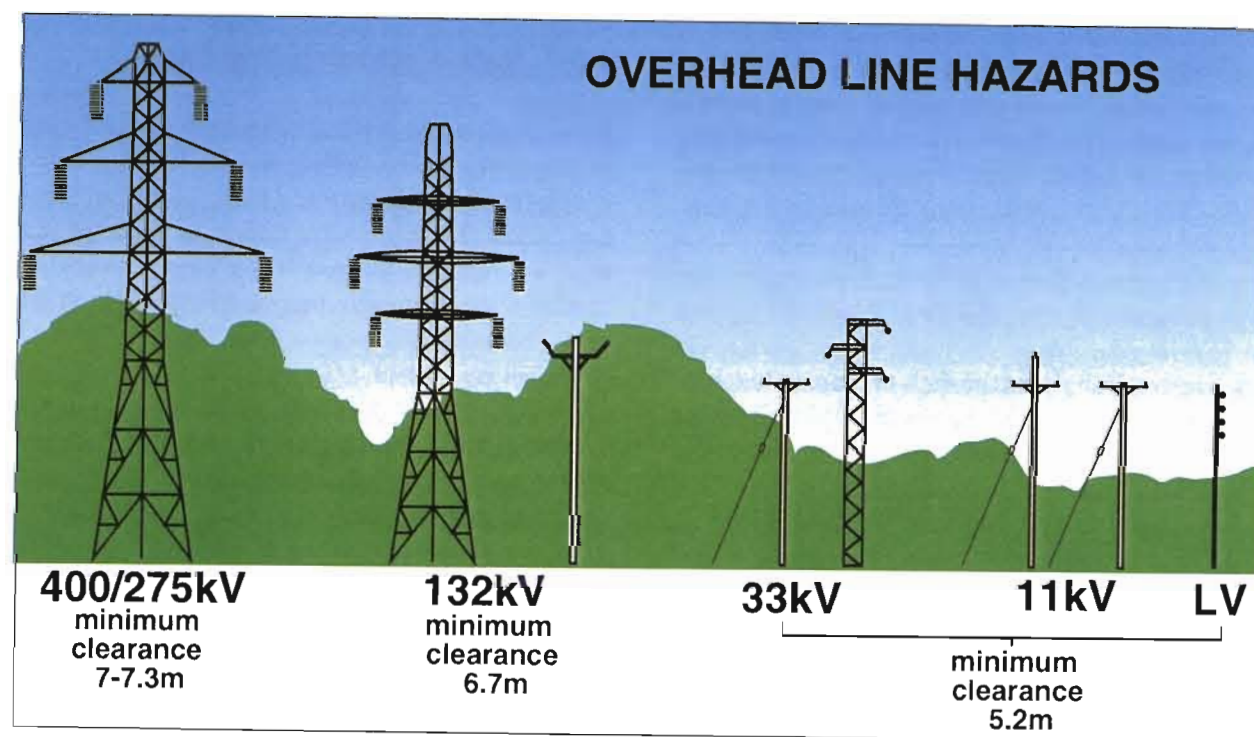


Figure 4.1 Overhead line hazards: transmissions towers (pylons), poles and cables – minimum ground clearances.

Minimum Safe Approach Distances (for the electricity supply industry)

Rescues	Minimum safe approach distance
When carrying out a rescue in the vicinity of overhead lines, substations and other electrical equipment belonging to the electricity supply industry	5 metres
Other Operational Incidents	Minimum safe approach distance
Not using hose	
When using ladders/aerial appliances or tall equipment	10 metres or 20 metres in training
In dense smoke or flames approaching conductor	10 metre corridor
Using hose	
When using hand-held jets	20 metre corridor
When using monitors (ground or aerial)	30 metre corridor

- If crossing under overhead lines with ladders or tall equipment the equipment should be kept horizontal and as near to the ground as possible.

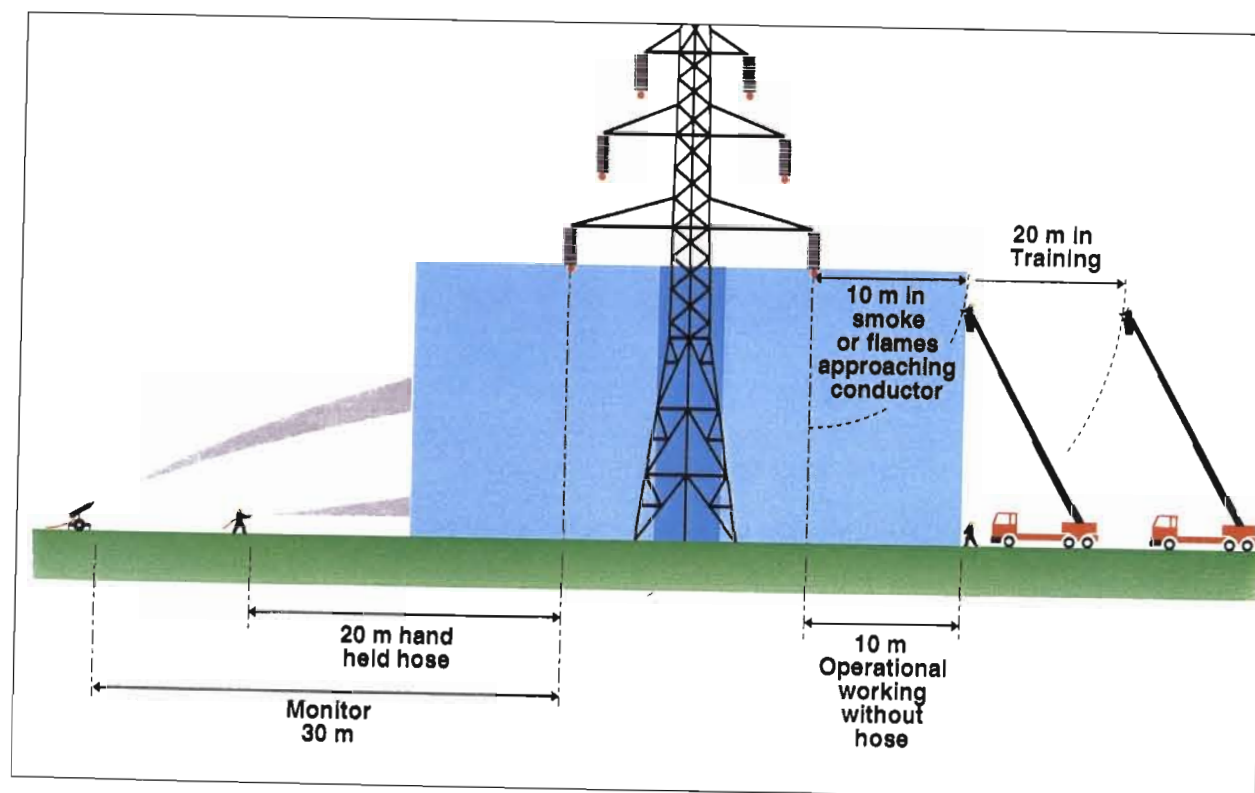


Figure 4.2 Minimum safe approach distances.

NOTE: Minimum Safe Approach Distances on Railways

Because of differing operating circumstances to the electricity industry RailTrack recommend that, except for rescue purposes, no part of a firefighter's body, tools or water jets should come within 2.5m of the overhead line equipment (OLE) or anything in contact with it, nor should a firefighter go above the top window level of a carriage or above the sides of other rolling stock (when the train is on the track) until advised by a responsible railway official that the current has been cut off.

Rescues

If carrying out a rescue firefighters must not touch an injured person if this means that they would have to come within one metre of live OLE or if the person is lying that close. On a conductor rail system, not exceeding 750V dc, a person in contact with the live rail should not be touched. Firefighters should normally wait for the current to be cut off in either case. If this cannot be done without undue delay, a dry rope or wooden pole may be used to push, or pull, an injured person away from live apparatus.

4.4 Use of Rubber Gloves

The special electrical rubber gloves or gauntlets (rated at 3300V) carried on many fire brigade appliances have their greatest use in dealing with low voltage systems normally found in business, industrial and private premises. They should be worn when removing persons from contact with electric wiring, for moving electric wiring which may prove a danger to operations and other work of a similar nature.

It should be noted that electricity regulations do not permit any person to be engaged in any work activity on or near any bare live conductor unless special precautions are taken.

Because of the increased danger of high voltage, it is not generally advisable to undertake any work near or approach any live conductors or damaged insulated cables. However, there may be some circumstances where the use of appropriate electrical rubber gloves may provide protection from electric

shock. In such cases it is necessary to ensure that the system voltage does not exceed the safe working limit of the gloves (normally rated at 3300V). This means that for most purposes gloves can only be used on domestic low voltage cables and equipment or appliances using domestic voltages.

Where system voltages exceed 3300V, or it is not possible to verify the actual value, the only safe course of action is to ensure that the supply is cut off and declared safe to touch.

Rubber gloves are generally stowed in waterproof containers and should be kept in sealed plastic bags following testing. It is necessary to ensure good maintenance as any dampness or damage, including quite small holes, will reduce the insulation effect of the gloves.

All rubber gloves should be regularly tested and when they are in use then every effort should be made to keep them dry

4.5 Removing Persons from Electrical Contact

(a) General

The human body has a relatively low resistance and therefore acts as a conductor of electricity, a condition which is greatly increased if the skin is wet. Therefore, if a person is in contact with live electric wiring, their body will form part of the circuit and any attempt to touch them is equivalent to touching the circuit. The same precautions must be taken as if it were necessary to touch the wiring.

For low voltage it is always preferable to isolate the supply and where high voltage above 3300V is involved this is ESSENTIAL.

At low voltages or at voltages known to be less than 3300V rescue from live conductors is possible using rubber gloves and/or insulating items such as a dry line, dry wooden stick or a length of dry hose. Care must be taken to ensure that any item used is free of metallic strips along its length and that any metallic attachment such as a hose coupling, does not make contact with live conductors and cause electrical flash-over or explosion.



Figure 4.3 Death can occur if you touch a conductor or a person or object in contact with a conductor.

(Photo: Electricity Association)

Firefighters must ensure that they DO NOT TOUCH any conductor, or any person or object in contact with a conductor

On normal household lighting and power circuits, it will suffice if several thicknesses of a dry non-conducting material, such as sheets of dry newspaper, a coat, rug, rubber gloves, etc., are used.

Immediately a person has been removed from an electric current, even though signs of life may be absent, resuscitation should be carried out and only discontinued when the patient revives or a doctor pronounces them dead.

(b) Overhead lines

It is extremely dangerous to climb tower structures or poles carrying high voltage lines, and even more so when additional equipment, such as transformers, switchgear or boosters, are mounted on them.

- As a general rule, no tower structure or pole should be climbed without authorisation and a clear indication from an 'authorised person' of the owning electricity company of the dangers and of the minimum distance necessary for safety.
- In particular, no rescue of persons on live high voltage conductors should be attempted until full clearance has been obtained from an engineer of the owning electricity company.
- Unless under conditions closely controlled by an 'authorised person', the manoeuvring, or use of metal, or metal reinforced, ladders or other metal objects in the vicinity of towers or transmission lines should never be allowed.

Occasions will undoubtedly arise where circumstances demand action by firefighters without technical supervision, and it is impossible to set out in detail the precautions necessary to ensure electrical safety in all instances. Initial action should ALWAYS be to contact the appropriate control centre at least to obtain verbal advice.

Identification of the tower structure concerned is of the utmost importance, and any identification markings on tower structures must be given if possible. A plate is fixed on the side of tower structures normally facing the nearest road, giving the route letter and tower number.

Circuit colours are also shown on colour plates fixed to an adjacent side of the structure and these are easily visible from ground level. Tower structures in the immediate vicinity of a fire need not be approached because information taken from adjacent structures is usually adequate for identification purposes.

In the case of trespassers in proximity to live Electricity Supply Industry (ESI) plant, immediate action is not necessary if the persons at risk can be persuaded to remain where they are until the arrival of ESI staff. Where conductors have fallen to the ground, all that is usually necessary is for people to be kept as far away as is reasonably practicable until the arrival of ESI staff.

A particular rescue problem arises where overhead transmission lines have fallen on to vehicles, or a vehicle is in contact with them. Ground clearances of lines are sometimes as low as 5m at mid-span and this may be further reduced by ice or snow

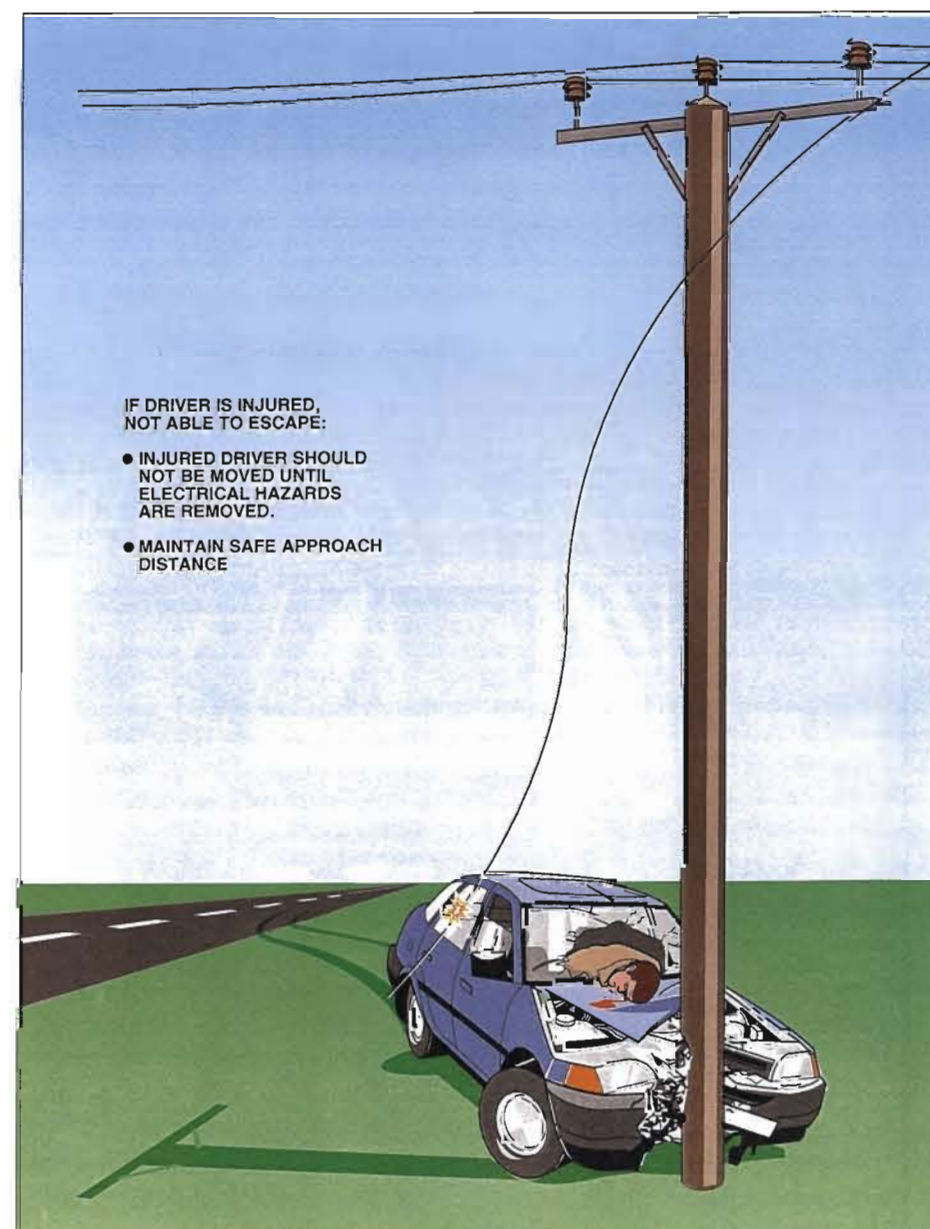


Figure 4.4 Recommended actions to be taken when an overhead line is in contact with a vehicle.

loading conductors. Clearances can be reduced by earthworks or tipping without the knowledge of the Electricity Company. Any vehicle in contact with power lines should be treated as 'live' even though the lines may appear to be dead. Generally, any person within a vehicle is quite safe from electrocution as long as they stay within the vehicle. Electrocution may take place if any person inside

a vehicle attempts to leave it and makes contact with the ground and any part of the vehicle at the same time.

Provided that there is no hazard to the vehicle e.g., fire, leaking hazardous load, etc., they should stay in the vehicle until an Electricity Company official confirms the line to be safe. (See Figure 4.4)

If any part of the vehicle touches an overhead line the driver/passenger/s should:

- **STAY IN THE VEHICLE, OR TRY TO DRIVE CLEAR**

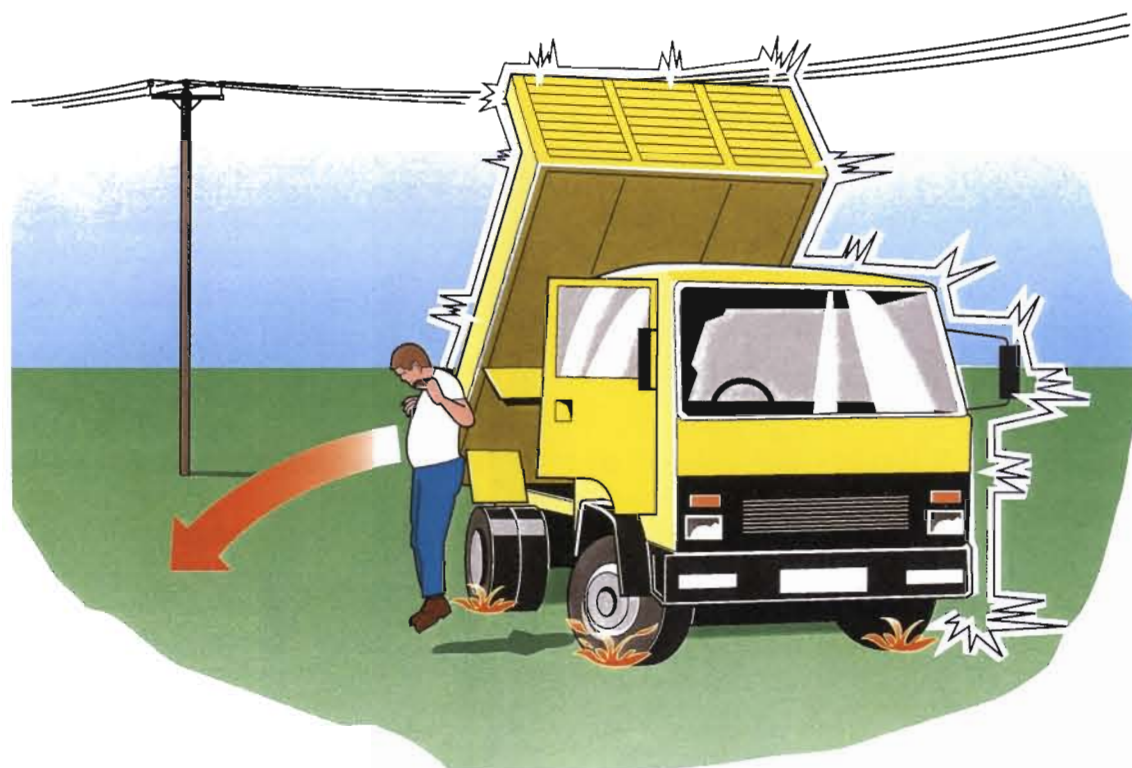
If not possible or if the vehicle catches fire

- **JUMP WELL CLEAR WITH BOTH FEET TOGETHER - DON'T CLIMB DOWN**
The metalwork of the vehicle may be **LIVE**

- **NEVER TOUCH THE VEHICLE ONCE THEY ARE ON THE GROUND**

- **RUN WELL CLEAR WITH LEAPING STRIDES AND STAY WELL CLEAR**

A number of fatal accidents have resulted from people returning to the vehicle.



If anyone is unable to jump or is trapped in the vehicle they should be left there until an Electricity Company Official confirms the line to be dead or earthed.

Figure 4.5 Recommended actions to be taken if uninjured driver or passengers have to leave the vehicle.

If it is necessary for the driver or passenger(s) to leave a vehicle they should jump well clear of the vehicle ensuring that they do NOT touch the vehicle and ground at the same time and land with both feet together. (See Figure 4.5)

They should then either jump away with both feet together or hop away with only one foot in contact with the ground at the same time. This is to avoid the danger of receiving a shock through the feet in the area where a voltage gradient in the ground is present because of direct, or indirect, contact between an overhead line and the ground.

Power lines found lying on the ground, even those apparently for low voltage, should NOT be approached until it has either been confirmed by an 'Authorised Person' that it safe to do so, or unless rescue from a line which has been positively identified as LOW VOLTAGE is involved.

Low voltage lines can be identified as:

- lines going into domestic premises.
- generally, low voltage lines are on wooden poles and uninsulated.

However, it MUST be remembered that many wooden poles carry High Voltage lines. All poles carrying High Voltage lines SHOULD carry an appropriate warning sign (see Figure 4.6).

DO NOT take the lack of a warning sign on a single pole as sufficient evidence that it is a low voltage line. Other nearby wooden poles should also be checked for warning signs.

- conductors are in vertical formation.
(usually between 2-6 conductors).

If the overhead line has been identified as low voltage, rescue of a person who it is reasonably thought to be alive can be undertaken provided that the procedures set out in 4.5(a) above are complied with. Overhead low voltage lines SHOULD NOT be moved as it can cause arcing, which may burn a person if the conductor is touching them or ignite any petrol vapours in the area.

IF IN DOUBT TREAT AS HIGH VOLTAGE AND STAY WELL CLEAR

In some instances transmission lines can still be live with one conductor on the ground. In other cases, it is possible for a line to be re-energised whilst the conductors are being moved.



Figure 4.6 Wood pole carrying High Voltage overhead lines. Only HV poles carry a warning sign.

(Photo: East Midlands Electricity)

It should be remembered that in some circumstances overhead lines may, often, not be required to be isolated, to permit access without appreciable delay. The sudden interruption of electricity supplies may itself endanger life: hospitals, lifts and cranes are typical examples, and the interruption of an important connection between the system and a power station, for instance, may affect whole areas of the country.

In the light of the above, requests for switching out of circuits should only be made by the Officer-in-Charge of the incident who should have assessed:

- the degree of danger at the scene of the incident; and
- the alternative solution of keeping firefighters and equipment clear of possible risk.

If it is felt justified to switch out the circuit then a request should be made to the appropriate Grid

Control centre giving the following information:

- Location;
- Voltage;
- Route letters and tower number; and
- Circuit numbers.

A circuit cannot be switched off immediately and may have to be earthed. The Officer-in-Charge of the incident should wait until the Grid Control Engineer or Company Engineer has confirmed, either directly or through the respective Fire Brigade Control, that the circuits have been taken out of service before it can be assumed safe to work on, or in the vicinity of, the lines.

RESCUE FLOW CHART

To attempt the rescue of a person injured by, or in the vicinity of, electricity follow the chart below.

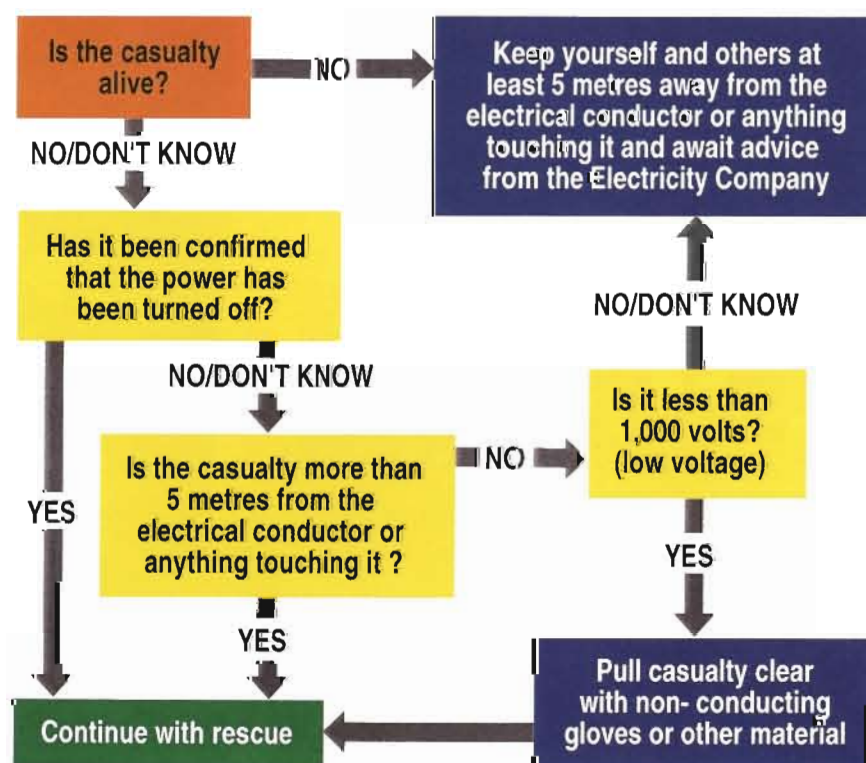


Figure 4.7 Rescue Flow Chart showing the risk assessments that should be made when attempting a rescue in the vicinity of electricity.

Electricity

Chapter

5

Chapter 5 – Fire-fighting procedures

General

(a) Liaison

Incidents involving electricity will present particular hazards which require pre-training and planning if they are to be tackled successfully.

There should be close liaison both before and during an incident. Pre-planning visits and on-site training exercises should be arranged to ensure that proper risk assessments are carried out and personnel are familiar with plant and processes before an incident occurs.

Emergency procedures should be determined with the site staff and the fire service. The procedures should be documented for reference both during an incident and during training sessions.

(b) Equipment isolation

In all cases involving electrical apparatus the first essential is to ensure that the apparatus is electrically isolated and safe to approach. In large installations this will be carried out by an 'Authorised Person' of the electricity company or, in a smaller installation, by an employee of the operator at the premises concerned.



Figure 5.1 Close liaison between the Brigade and local Electricity Company, both before and during an incident, is VITAL.
(Photo: Electricity Association)

Electrical or associated equipment should NOT be touched or even approached unless it is confirmed to be isolated and safe.

(c) Extinguishing media

Once electrical equipment is confirmed to be isolated and safe then the appropriate extinguishing media for the material involved in fire can be used.

If the power supply cannot be isolated then the fire must be attacked in a way which will not cause danger to the firefighter, i.e., by the use of non-conducting extinguishing media. Carbon dioxide, vaporising liquid, powder, dry sand, ashes, etc., are the substances normally used. Extinguishers or supplies of these materials will usually be found in larger premises where electricity is generated or consumed and their location and availability should be noted during pre-planning.

Foam can be used for fires involving oil, provided that there is no danger of the stream reaching apparatus which is still live. Once foam has been applied it should be monitored to ensure that it does not flow and come into contact with live equipment.

Carbon dioxide or vaporising liquids do not damage electrical equipment. This is an extremely important factor when dealing with incidents involving delicate and complex apparatus such as that found in switchboards in generating stations, substations, telephone exchanges, or other electronic equipment such as computers. Sand should only be used where it will cause little or no damage, such as on cables, and never on machinery with moving parts.

In order to protect firefighters when extinguishing a fire known to have been started through an electrical fault, the power supply must always be switched off before tackling the fire in order to

protect firefighters against electric shock. This will also help to guard against a continued supply causing re-ignition.

5.1 Fires in Generating Stations

(a) General

In nearly all cases, generating stations are continuously staffed at night although some small gas turbine stations may be remotely controlled. Usually, therefore a fire is likely to be discovered in its initial stages and dealt with by the station fire team.

The generating station will have a fire emergency plan and, although similar in content, these plans may vary according to location. Fire brigade personnel should make themselves aware of the procedure to be observed in each instance through regular liaison, pre-planning meetings and on-site training exercises.

In all instances the PDA should be escorted from the gatehouse to the incident and should not stray un-escorted to any other parts of the site. Generating station sites are large and it is recommended that rendezvous points and vehicle marshalling areas should be established with good radio communications to ensure the safe deployment of appliances at a large incident.

(b) Incident controllers

The generating station will have an "incident controller" and it is essential for the safety of the on-site operatives and LAFB fire-fighters that the fire brigade officer and incident controller should establish and maintain effective lines of communication.

This liaison is vital and should be established immediately upon arrival.

(c) Roll call

As with any emergency incident the prime consideration should be the risk to life of people either involved or likely to be involved. If evacuation has already taken place then an immediate roll call should be carried out. If evacuation has not taken place then consideration should be given to the

need for partial or total evacuation depending on the scale and location of the incident.

(d) Fuels

It is likely that various types of fuel will be present in a power station e.g.,

heavy fuel oil, gas turbine oil, diesel oil, liquid petroleum gas, natural gas and coal are common.

Some fuel oils may be pre-heated to make them more fluid and easier to ignite in boilers. Such pre-heating also makes these oils more susceptible to accidental ignition where a spill and free flow of fuel has occurred.

Pre-planning should take account of what fuels are available at the site, what quantities, their location and what arrangements there are for protecting or moving fuel stocks in emergencies.

When an incident occurs the pre-planned information in respect of the fuels on site should be used to ensure that fuel stocks are protected from the possibility of any fire spread.

(e) Hazardous substances

Bulk storage of hazardous substances such as methanol, propane, hydrogen, methane, chlorine and oxygen may also be found.

The pre-planning arrangements should ensure that procedures for dealing with such substances are established prior to an incident.

If hazardous substances are encountered which have not been planned for in the pre-planning arrangements then normal liaison with the station management should take place and chemical information sought in the usual way.

(f) PVC insulation

Large quantities of cables will be found in generating stations. The cable insulation is usually PVC and any propagation of a fire involving that insulation can produce large volumes of toxic and irritant smoke which will contain hydrogen-chloride gas.

When dealing with incidents which may involve such substances then appropriate chemical protection and breathing apparatus should be employed.

(g) Firefighting systems

Generating stations are usually equipped with fixed fire protection systems which cover most plants and equipment. Private hydrants will usually be available.

The type, location and working detail of any fixed installations should be established during pre-planning.

When an incident occurs it should be quickly established whether or not any fixed installation system has operated. If a fixed installation system has not operated it may be desirable to operate the system manually to assist in bringing a fire under control. In either case consideration should be given to the possibility of additional protection being needed for firefighters e.g., breathing apparatus.

In the vicinity of the turbo alternators and boilers there is usually a high pressure hydrant fed by pumps for the high velocity water-spray protection. These high pressure mains should not be used for firefighting unless specifically agreed with the generating company. Usually there is a lower pressure hydrant system available within the turbine hall for general firefighting use and additional water mains will usually be available outside the building.

The pumps supplying water mains within the power station site may not start automatically and it may be necessary to have them started manually.

The use of water in some areas of a generating station may not be safe, and areas where water may be used should have been decided beforehand in consultation with the Electricity Company Engineer.

(h) Cable racks/Tunnels

Cable racks, especially in large ducts and tunnels, will be found at generating stations and will present their own specific problems of access. Guidance on dealing with incidents in tunnels can be found in Technical Bulletin 1/1993 which should be consulted at the pre-planning stage.



Figure 5.2 Cable rack and firefighting system.

(Photo: HM Fire Service Inspectorate)

5.2 Fires in Transformers

(a) General

Most fires involving transformers are caused by an electric arc under transformer oil. Such an arc may be caused by an internal transformer fault and can produce hydrogen, acetylene and methane. Any explosive gases produced may ignite and the resultant violent explosion will rupture the transformer tank and cause burning oil to flow or even be sprayed over a considerable distance.

It is vital, therefore, to carry out firefighting from a distance, taking advantage of available protection and the use of ground monitors should be considered.

A firefighting attack should only be made when the extinguishing or controlling media to be used has been established and there are sufficient stocks to sustain the operation.



Figure 5.3 Burning transformers may explode and spray burning oil over a considerable distance.

(Photo: West Midlands Fire Service)

(b) Automatic protection

Transformers at power stations usually have automatically actuated, high velocity, water-spray protection and at a fire incident it should have operated. If the system has not operated consideration

should be given to manual operation to assist in fire-fighting operations.

Remote transformers in substations are not usually protected, in this way, except in some inner city areas.

(c) Firefighting

The operating temperature of a transformer at the outbreak of fire may be quite high (100°C) and, as a consequence, the spread of fire can be rapid.

The situation may be worsened due to the likely delay in the start of fire-fighting operations which will be necessary to ensure isolation and earthing of the affected transformer.

Whilst awaiting an assurance that isolation of the transformer has been carried out steps should be taken to protect surrounding property and water and foam supplies gathered and made ready.

If the transformer is not separately banded, burning oil could flow around others in the group, or 'bank', and rapidly involve them also. In such circumstances it will be essential to lay and maintain a foam blanket over the affected area as soon as possible. Bearing in mind the possibility of an

explosion this should be done from as far away as practicable and taking advantage of available protection if possible.

The transformer oil cooler banks, if they are free standing, may collapse, and the porcelain insulators may shatter if they come in contact with fire or water jets. **If porcelain bushings or insulators do shatter, hot pieces of porcelain, which may be razor sharp, can be thrown over considerable distances.**

(d) Ionisation

Where transformers, which are involved in fire, are fed from overhead transmission lines, the heat and smoke may cause ionisation of the air surrounding the conductors. This has the effect of increasing the electrical conductance of air to the point where it will allow electricity to flash from phase to phase, phase to earth or to adjacent structures, trees or fire brigade equipment. Firefighters,

therefore, should be aware of this possibility and a working "corridor" with a minimum distance as set out in Figure 4.2, page 42 should be maintained either side of overhead lines.

As with any overhead line, ladders and other long items of equipment should not be used in the area.

(e) Oil-filled switchgear

High voltage switchgear, if oil-filled, is often covered by a system which automatically operates to extinguish or control a fire. If such a system is installed but not operated then consideration should be given to manually operate it to assist in firefighting.

Where such a system is not fitted, once it is certain that the supply is switched off and the equipment is earthed, fires involving oil can be extinguished by the use of foam or, where appropriate, water fog.

As with transformers, oil-filled switch-gear, may, if a short circuit occurs, violently explode and spray burning oil over a considerable distance and this should be borne in mind when positioning firefighting personnel and equipment.

(f) Polychlorinated Biphenyl's (PCB's)

PCB's, which are used in some transformers and other electrical equipment as an insulating liquid, are highly toxic and have harmful environmental effects if released, as they are not biodegradable.

Since 1971 all new transformers must, if they contain PCB's, indicate clearly that they do so. Transformers built prior to that date were not required to be so labelled and some, though not all, have been retrospectively labelled. Some owners, with transformers on their properties, are unaware that they contain PCB's, and this can mean some LAFBs have not been given advance warning of the presence of PCB's and are unaware of the need to take special precautions against them when attending transformer fires.

Changing the liquid in a transformer from PCB to an alternative coolant fluid is known as retro-filling. Although this can reduce the PCB level to

below the permissible level of 50 ppm (0.005%), leaching from the insulation and core, during service, can mean that the PCB level will rise again above the permissible level.

Firefighters should be aware of this leaching process and, until expert monitoring shows otherwise, regard an oil filled transformer or oil filled switchgear as dangerous and requiring full protection procedure including the wearing of breathing apparatus. (It can be safely assumed that transformers and switch gear belonging to member companies of the Electricity Association, i.e., the National Grid, the Generating Companies and the Electricity Companies, do not contain PCB's or are retrofilled. It is only in industrial and commercial premises, and some railway premises and rolling stock, that equipment which still contains PCB's and/or has been retro-filled may be found.)

Heating or burning of PCB's greatly increases the hazards as the production of highly toxic gases and smoke can occur which could result in soil and surface contamination. **At such incidents, therefore, as well as protecting firefighters with full protective clothing and breathing apparatus, consideration should also be given to evacuating the area covered, or likely to be covered, by the resulting smoke/gas cloud.**

Strict precautions should be taken to ensure that any spillage does not enter sewage systems or water courses. All spillage, including water used for decontamination purposes, should be contained for specialist disposal as PCB's are not biodegradable.

The appropriate authority should be notified where there is any likelihood of products from a fire, which involves PCB's, entering water courses.

If PCB's are spilled or leaked, the Officer-in-Charge of the incident should request the Local Authority to arrange disposal of the PCB's and any material which they may have contaminated.

Firefighters must NOT attempt disposal themselves.



Figure 5.4 400 kV SF₆ Gas Insulated Switchgear (GIS). (Photo: HM Fire Service Inspectorate)

(g) Residual charges

Switching off the current to a high voltage installation, such as a cable, transformer or switch-gear does not necessarily render it safe as a residual charge of electricity may be present in the apparatus. This charge is sufficiently powerful to cause electrocution.

For this reason electrical equipment must always be 'earthed' before it is safe to touch. This earthing is a separate physical technique and should only be carried out by an 'Authorised Person'.

(h) Entering protected premises

Where transformers, switchgear, etc., are protected by fixed carbon dioxide or vaporising liquid installations and the installation has operated,

The electricity company's 'Authorised Person' should be consulted before any entry to the enclosure is attempted.

Any firefighter entering such enclosures SHOULD be wearing breathing apparatus.

5.3 Fires On or Near Overhead Power Lines

Apart from transformers and switchgear, or apparatus containing oil, there is little fire risk involved where transmission and distribution is carried out by means of overhead lines, although where the lines are carried on wood pole supports, and the route lies across scrub, heathland or similar country, there is some slight risk of scrub fires setting the wood pole supports alight and bringing the cables down.

Fires, especially those involving smoke with a large carbon content, e.g., rubber tyres, certain types of plastic, forest and heath fires etc., beneath or near overhead transmission lines, may cause ionisation of the surrounding air and allow arcing to take place (see 5.2(d) above). In addition heat from large fires in the vicinity of overhead transmission lines may cause the lines to stretch and sag. If there is any doubt about the safety of the lines then the electricity company should be notified.

There are two further major hazards to be considered when using hose near to overhead power lines:

- (i) A high pressure jet playing on an overhead line with horizontal conductors may cause the conductors to clash and produce arcing. This could lead to a breakage of the conductor resulting in live conductors falling to the ground; and
- (ii) A water jet playing directly on to overhead conductors can result in earth leakage currents through the water jet stream to ground. This may cause the branch to become live with potentially fatal consequences.

There are many factors governing the amount of earth leakage current flowing down a jet stream, but it is not practicable to take all of them into account when fighting a fire.

Therefore, to minimise the risk of danger from these hazards:

Water or foam should NEVER be sprayed on any electrical apparatus, or any apparatus which has not been declared to be dead by an 'Authorised Person'.

The recommended safe approach distances quoted in 4.3. 'Safe Approach Distances' should be observed.

5.4 Fires in Substations

(a) Grid substations

On the grid system, substations are generally of the outdoor type, but some may, occasionally, be indoor or even underground.

Because the voltages employed range from 6,600 to 400,000 volts, it is essential that firefighters do not enter the substation, or attack any fires which might occur in them, until they have received notification from an 'Authorised Person' of the Electricity Company that entry and tackling the fire can be safely carried out.

Not many sub-stations are permanently staffed and a sub-station attendant will not, usually, be authorised to allow entry for firefighting.

The LAFB should, by co-operation with Electricity Company officials, know the status of all sub-stations in its area and the correct procedure to take for each one.

(b) Rescue

As a general safety rule,

No grid substation should be entered until an assurance has been received from an 'Authorised Person' that this can be safely done.

There are, however, two exceptions when entry can be considered.

These exceptions are:

- (i) if a fire is at **ground** level; or
- (ii) if a person is lying on the **ground** inside the substation and apparently injured.

The reason for this is that live open high voltage bushings are seldom located less than 2.5 m above ground level. When this is not possible, protective screens are provided round the equipment for safety.

However, once inside,

Firefighters must NOT

- **climb equipment**
- **use ladders**
- **direct any jet or spray above ground or beyond any fitted safety screens.**

It should be understood that the statutory rights of entry to substations only apply to **fire** incidents.

Should a person be seen lying on top of a transformer, switch, or, anywhere else above ground level, **they must NOT be touched until word is received from an 'Authorised Person' of the Electricity Company that it is safe for rescue work to be carried out.**

Care should be taken when attempting to move injured people, even if they are lying on the ground away from a live power line as either the surrounding ground or the person could have a residual charge of several thousand volts.

(c) Firefighting

Many substations in rural areas are situated at a considerable distance from water mains, or any static supplies. Fires involving large transformers will require large quantities of water and foam concentrate. Planning pre-determined attendances

for such a risk should therefore take account of the possible need for extra pumps for water relaying and a foam tender and/or the availability of foam stocks.

(d) Other substations

Substations, other than grid substations, are of various types, and those which the firefighter is most likely to meet are located on commercial or industrial premises, where they may be either be indoors or outdoors.

These substations operate at high voltages, and they should be treated as highly dangerous until information has been received from an 'Authorised Person' of the Electricity Company that the electricity supply has been isolated and the installation is safe to approach.

Similar precautions must be taken on industrial premises containing substations operated by the factory occupier.

5.5 Fires in Cable Boxes

Where the transmission or distribution of electricity is carried out by cables laid underground, the chances of fire occurring are remote except at a cable or link box, or a feeder pillar where the main cables may divide into a number of circuits.

Incidents caused by gas generated by faulty equipment are rare, the most common cause of gas ingress is leakage from gas mains. A fire may be caused by an explosion which may blow off the cover of the cable or link box. This can occur through a fault in the cable with the consequent formation of an arc which ignites any flammable

gas generated during the development of the fault or if an external source of ignition is introduced without first venting the box.

Should a fire occur in an underground cable resulting in the street box cover being lifted and fire is actually visible, then CO₂ or Dry Powder should normally be used.

Another option is to use a small quantity of dry sand (damp sand MUST NOT be used) to extinguish any fire in a cable box. In some power stations and sub-stations dry sand is available. However, in the case of street boxes it should be remembered that as burning cable insulation gives off dense fumes which can fill the cable ducts, and if a street box is filled with sand, the duct may become sealed. The heated, expanding gases could either blow out the sand or, more likely, cause the fumes and fire to travel along the duct to other boxes, worsening the situation.

Firefighters should protect any exposed property adjacent to the street box and await the arrival of representatives of the electricity undertaking, who should have been notified.

All personnel, and the public, should be warned to keep away from adjacent street boxes, whether above or below ground, in case further explosions take place.

Underground cable or link boxes (Figure 2.22) and feeder pillars are generally located sufficiently far from a building for any risk of fire spread to be unlikely but of course such an eventuality should not be discounted.

5.6 Fires in Industrial Premises

Due to a high demand for electrical power, some industrial premises have a substation on their premises which often contains a transformer and switchgear. The supply is invariably alternating current, although, if direct current is required, the substation will also contain converting plant.

In both cases, it should be assumed that the incoming supply is at high voltage and, before attacking the fire, it is most important that liaison is set up with an engineer from the premises who can give

a positive assurance that the supply is isolated and safe to approach.

If an assurance cannot be obtained from an on-site engineer or there is any doubt about the status of the equipment then the supply should be assumed to be live and assistance should be sought from the local electricity company.

From the substation or switch-room the supply, which is then usually at 230/400 volts (although some equipment such as motors may operate up to 11 kV), generally passes through a local switch and fuse board before it is conveyed to the individual apparatus.

In the case of a small fire, it may only be necessary to isolate circuits near the fire, and this should be done by the plant engineer.

5.7 Fires in Private Dwellings

The majority of fires of electrical origin which occur in private houses are caused by faulty electrical appliances or circuits, or by carelessness.

Where incidents involving electrical equipment and appliances occur, the switch on any apparatus should not be relied upon for isolating the apparatus. Instead the apparatus should be switched off at the wall socket. For complete safety the plug should be removed from the socket.

Supply voltages in private houses do not normally exceed 230V. There are however some domestic properties where the demand for electrical power is high e.g., where there is an extensive use of night storage heaters, and the property may be served by more than one phase and so voltages of 400V could be encountered.

Care should be taken when dealing with a fire involving the meter and fuse installation of a private house as it is generally mounted on a wooden board which may fall away from the wall when it burns through; the ends of the service cable may then be exposed.

The correct action at a fire of this type is to extinguish the flames and, as soon as possible, isolate the supply. At any fire involving electric cables



Figure 5.5 11kV Distribution Sub-Station transformer. (Photo: Electricity Association)



Figure 5.6 230v overhead domestic line service. (Photo: HM Fire Service Inspectorate)

and installation, the Electricity Company should be notified, and the occupier advised not to approach or use the installation until it has been tested and rendered safe.

5.8 Fires Involving Storage Batteries

The traditional type of storage batteries are usually of the lead-acid or nickel-iron type and will be found in many electricity company and commercial premises and are also used in motor vehicles. Newer types of batteries, especially for use in vehicles are in the research stage and use substances such as sodium sulphur, sodium nickel chloride. Other substances which are now used in batteries are zinc and lithium.

(a) Lead Acid/Nickel Iron Batteries

When correctly installed and maintained, these batteries present little fire risk, but the unsuitable

conditions under which they are sometimes re-charged can frequently lead to a fire.

Hydrogen is released during the charging process and concentration levels of only 4% are sufficient to create an explosive atmosphere. If a source of ignition is introduced into a battery charging area, and the conditions are suitable, there is a risk of an explosion.

If batteries are involved in fire then the products of combustion will contain droplets of electrolyte (dilute sulphuric acid) which is both corrosive and poisonous.

Salt water should NOT be used on fires in which lead-acid type batteries are involved since, under certain conditions, free chlorine may be generated.

Because of the possibility of the presence of corrosive and poisonous electrolyte and/or chlorine when dealing with fires involving lead acid batteries the use of breathing apparatus and protective clothing

should be considered. Nickel-iron batteries which use alkaline electrolyte are free of this danger.

If a fire has been caused by a short circuit, the circuit should be broken, if possible, by opening the switch or disconnecting the leads, otherwise the conditions which caused the fire will persist until the battery is fully discharged. The fire should, preferably, be tackled with a hose-reel fog or spray, not because of the risk of shock, but because needless damage may be caused if a high pressure jet is allowed to strike the cells. Water should be kept away from cells which are not involved in the fire, because it will adversely affect the electrolyte. Any electrolyte which has been released by the failure of a cell should be diluted with a stream of water.

(b) Sodium Sulphur Batteries

This type of battery, if involved in fire, will give off toxic Sulphur Dioxide and Hydrogen Sulphide fumes. A fire originating inside this type of battery can take up to 30 minutes to become apparent and be very difficult to extinguish as the reactive prod-

ucts needed to sustain the fire are contained within the battery. If a fire does occur it may burn for up to 2 hours.

To protect firefighters against the toxic fumes breathing apparatus and protective clothing should be worn and all others should be evacuated to at least 10 metres of the incident.

The fire should be controlled and the surrounding area protected using water spray. Halon or Carbon Dioxide should NOT be used.

(c) Sodium Nickel Chloride Batteries

At the time of writing (1997) it is believed that this type of battery will not produce corrosive products or generate high pressures.

5.9 Fires Involving Uninterruptible Power Supplies (UPS)

An Uninterruptible Power Supply (UPS) is a device that cleans up mains power and also pro-

Figure 5.7 An 'individual' UPS serving just a single piece of electronic equipment.

(Photo: Greypoint Marketing Ltd/DAKER)





Figure 5.8 Large UPSs can serve all electronic equipment in a building.

(Photo: Merlin Gerin Ltd)

vides back-up power from its battery to a computer or other electrical equipment e.g., telecommunications or medical equipment, during a power blackout.

There are two main types of UPS.

One type is used for individual pieces of electrical/electronic equipment and are commonly found associated with computers, especially personal computers. They vary in size considerably. 'Desk

top models', which typically have a power output of about 150/300 VA, are approximately the size of a large shoe box or, for 'slim line models', the size of an attache case. Standing floor models vary in size from a small suitcase to models the size of a small refrigerator with, typically, power outputs of between 5-20 kVA.

The other type is linked to a number of pieces of equipment in a room or, in the case of the very largest types, to all the equipment in a whole build-

ing. These vary in size from a medium sized refrigerator to a large wardrobe and have power outputs of up to 100 kVA for the largest models. (Figures 5.7 and 5.8)

Hazards

One of the hazards posed by UPSs is that they provide back-up power in an emergency. Firefighters may go into a room expecting all electrical/electronic equipment to be "dead" because the mains power is off. But, because the equipment is linked to an UPS they may discover that the equipment is "live".

In the case of the larger UPSs which provide back-up for a whole building there should be a "cut-off" switch for it near the "cut-off" switch for the mains power and thus it should not pose a problem. However, the smaller individual UPSs can pose a particular hazard as they will stay "live" until their own individual on/off switches are operated.

Firefighters should therefore treat all electrical/electronic equipment, especially personal computers, as potentially being "live" and not deliberately direct water upon them or come into contact with damaged or suspect equipment unless they have been assured that the item does not have an UPS or that, if it has, it has been turned off.

It should be remembered that an UPS system is installed to safeguard the electrical supply of vital or even life saving equipment and its dis-connection could have serious consequences. If possible, therefore, advice should be sought before such a system is switched off.

5.10 Fires in Motor Vehicles

Many fires in motor vehicles are caused by electrical faults. They normally result from short circuits caused by damage to, or deterioration of, the electrical wiring system.

Parts of the circuit may be overloaded by the attachment of additional equipment. As the wiring is normally permanently connected to the battery without a master switch, such fires may occur at any time and not only when the vehicle is in use. If

possible, one of the main leads from the battery should be disconnected to prevent the fault continuing. The fire can then be dealt with using any appropriate extinguishing medium.

In modern engines it is common to have components at dangerously high currents even when the engine is not operating. Although it will be safe to carry out normal firefighting with extinguishers or hose-reels etc., it is unwise to tamper with any electrical components within the engine compartment. Unless firefighters are fully conversant with engine components and their function then actions should be limited to battery dis-connection and firefighting only and other specialist equipment, including airbags, should not be interfered with.

Electric powered vehicles

Largely because of environmental concerns, considerable effort is being put into the development of electric powered vehicles. Because the traditional lead acid battery cannot provide sufficient power, prototype Sodium Sulphur and Sodium Nickel Chloride batteries (see Chapter 5.8) are being trialed in electric vehicles. If these trials are successful, these types of batteries (and other types in the research stage) may become common on the road presenting different problems from those posed by the traditional lead acid type of battery.

Appendices

- A1 Case Study: Transformer fire, November 1997
- A2 Electrical fire statistics
- A3 Map showing areas covered by Regional Electricity Companies
- A4 Electricity Association-Member Companies' Useful Addresses and Telephone Numbers

Case Study
Transformer fire: November 1997

APPENDIX 1



The following series of photographs is of an incident which occurred in an electricity substation in Belfast on 4th November 1997.

The incident was not terrorist-related and serves to highlight the duration and logistics involved in dealing with a fire of this type.

On receipt of the call at **0625** the predetermined attendance of 2 water tender ladders were mobilised, the electricity board informed and they confirmed that an engineer would meet the appliances.

On arrival, it was found that a large transformer within the substation was well alight and requests were made to boost water supplies.

Pumps were increased to 8 and a foam tender, emergency tender and water tankers requested. The following extracts show the subsequent development.

0756 Informative message stated that **'20,000 gallons of cooling oil involved.** Preparing for foam attack. Awaiting isolation of electrical supply.'

0818 Firefighting commenced. Breathing apparatus wearers with 5 x 450l/m foam branches. Department of the Environment requested to attend regarding potential for contamination of water courses.

0834 Make pumps 10 for personnel.

Pumps were subsequently made 11 and lorry loads of sand requested.

1126 An informative message reported 4 foam jets in use (450l/m), **10,000** litres of foam compound used. Pumping water from 500 metres away. Fire under control. Foam attack continuing.

1258 Informative – Foam attack stopped, 5 jets for cooling in use. 3,500 litres of foam compound on site, **12,500** litres foam compound used.

1814 Stop message sent.

After the 'stop' message, foam was used intermittently as well as cooling jets.

1146 on 5th November 1997

Last pump returned to Station.

A total of **20,500 litres of 3% Fluoroprotein Foam compound** was used as well as a small quantity of High Expansion foam. 100 tons of sand was also used.

Appliances attending:

- 11 Pumps**
- 2 Foam tenders**
- 1 Foam Trailer**
- 1 Emergency Tender**
- 1 Control Unit**
- 3 Water Tankers**



A similar type of transformer to that involved in the fire. (All photographs in Appendix 1: Northern Ireland Fire Brigade)







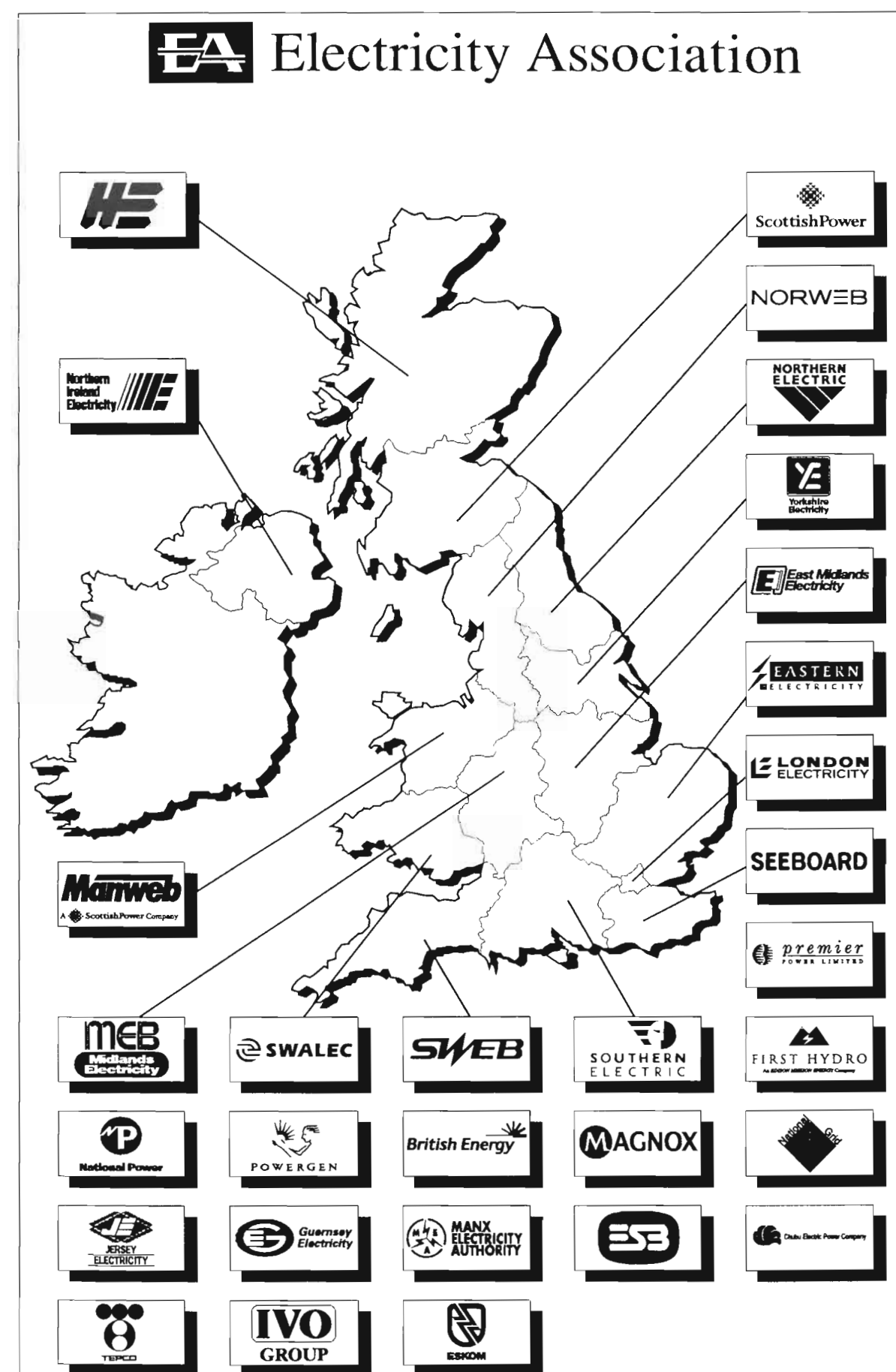
The transformer after the fire.

Shown below are some of the statistics relating to fires of electrical origin in 1994 (at the time of writing the latest year for which statistics are available). These figures are taken from:

Summary Fire Statistics – United Kingdom 1994
Home Office Statistical Bulletin

- Total number of fires in dwellings and other buildings:
approximately 107,000
- Faulty electrical appliances and leads caused approximately 8,100 fires (approximately 7.5% of all fires) which resulted in:
16 fatal casualties (approximately 4% of fatalities);
and
1,036 non-fatal casualties (approximately 10% of non-fatal casualties)

A fuller study of fires of electrical origin can be found in the Fire Statistics Research Paper – 1 “Accidental fires of electrical origin attended by local authority fire brigades in the United Kingdom, 1981–1988” published by the Home Office, October 1991.



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